

WHOLE SYSTEMS DESIGNING: TOWARDS A FRAMEWORK AND TOOLS FOR
TEACHING COMPLEX PROBLEM SOLVING

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Master of Arts

by

Pranav Gupta

May 2014

© 2014 Pranav Gupta

ABSTRACT

This exploratory study set out to understand how to ‘design’ change in this complex interconnected world - Whole Systems Designing (WSD). The purpose of this study is to (1) understand WSD skills; (2) prototype tools and methods to teach and measure them.

The literature on systems theory, design thinking and change leadership is reviewed to identify and present 18 WSD skills in principle and practice. Also, a framework for Whole Systems Change is offered as a first step for teaching these skills. A design study developed WSD card-set and evaluated its efficacy through a focus group study. The participants found it useful for explicitly discussing their personal design process. A research study which used network methods to map the learning behavior of 60 students found that educational background predisposes students to learn different skills and students from the same educational background and year in school have similar concept maps.

BIOGRAPHICAL SKETCH

Pranav Gupta received his Bachelor of Technology with major in mechanical engineering from Veermata Jijabai Technological Institute (VJTI), Mumbai in 2011. During these four years in VJTI, he led the Society of Robotics and Automation and conducted workshops and mentorship programs to popularize robotics among the undergraduates. He and his colleagues started Pratigya, a non-profit for building awareness about science and technology among K-12 school children. Following his aspiration to create learning opportunities through systems design he continued his studies for Master of Design at Cornell University. His research interests are focused on understanding social change, whole systems design and their relation to learning and skill building.

To my family,
Vipin, Poonam, Shivam and Pragya

ACKNOWLEDGMENTS

This thesis would not have been possible without the dedication and support of many people. First, I would like to thank Prof. Sheila Danko, for all her insight and effort in this work. She is a great mentor and has guided me to explore my research interests and passion. Her encouragement and feedback helped me generate this thesis and complete it. She was my committee chair and I could not have imagined having a more welcoming advisor. Prof. Brian Rubineau, my other committee member, stimulated this thesis by introducing me to the field of networks in a social network methods course. His simple explanations and valuable comments gave me astonishing clarity and made the whole process manageable. I'd like to thank Cornell University, Department of Design and Environmental Analysis; in particular, Peter Jackson, Yervant Terzian and Jack Goncalo for having open discussions and helping develop my ideas, and Doralee, Valerie, Tracey and Roberta for making the administrative process very easy.

Special thanks go to Derek Cabrera and Laura Cabrera who have been thoughtful mentors. Their insights helped me gain a wider perspective and appreciation towards the research process. I regard them as my American parents. They have taught me far too many things to account for and it feels like we have just begun.

Also, this thesis would not have existed if not the assistance given by Mihika Kulkarni during the writing process and Lucia Song, Ethan Arnowitz, Zoe Katz and Tina Lee during the two month long data analysis phase. Furthermore, I would like to thank all my friends who supported me throughout this process in many ways, especially, Susan Chung and Uchita Vaid.

The love and support of my family has empowered me all through my life. Time and distance is of no matter when it comes to family -Mom, Dad, Shivam and Pragya -there are truly no words that can do justice or describe how grateful I am for your support.

TABLE OF CONTENTS

Biographical sketch	...iii
Acknowledgements	...v
Table of Contents	...vi
List of Figures	...viii
List of Tables	...ix
Chapter 1: Introduction: Design in an era of complexity	...1
Chapter 2: Literature review: Understanding whole systems designing	...6
2.1 Identifying key skills of whole systems designing	...6
Coverage and synthesis criterion	...7
Broader context of the field	...10
Key variables in the field	...13
18 skills of whole systems designing	...17
2.2 An emerging framework for whole systems change	...21
Understanding “wicked” problems	...24
Structure of whole systems change	...25
Organization – An example of complex system	...28
Chapter 3: Design Study: Developing a teaching tool for whole systems designing	...31
3.1 Objective of the study	...31
3.2 Design approach	...32
3.3 Phase I - Design goals	...33
Message	...33
Tone	...34
Format	...34
3.4 Phase II - Design execution	...35
Design concept	...35

	Inspiration	...36
	Design process	...41
	First prototype description	...46
	Final design layout	...47
3.5	Phase III - Design evaluation	...48
	Focus group description	...48
	Participant perspectives	...49
	Modifications and recommendations	...51
3.6	Discussions – Implications for design educators	...52
Chapter 4:	Research Study: Understanding learning behaviors related to whole systems designing	...53
4.1	Objective of the study	...53
4.2	Research setting and data collection	...55
4.3	Methods	...56
	Content analysis	...56
	Statistical analysis	...59
4.4	Results	...63
4.5	Discussions – Implications for design educators	...65
	Limitations of the study	...68
Chapter 5:	Summary and recommendations	...70
5.1	A developing framework for whole systems designing	...70
5.2	An evolving tool for teaching whole systems designing	...71
5.3	Mapping student learning of whole systems design concepts	...73
5.4	Recommendations for future research and application	...73
Appendix A:	Whole systems designing: Card Set	...77
Appendix B:	Literature review scoring rubric	...87
References		...88

LIST OF FIGURES

Figure 1.1: Summary of research exploration	...4
Figure 2.1: Types of design	...21
Figure 2.2: Skills arranged from the perspective of sustainability along the y-axis	...27
Figure 2.3: Whole Systems Change Framework	...27
Figure 2.4: Whole systems change framework applied to an organization	...29
Figure 3.1: Cortical Homunculus: How our brain sees our body	...34
Figure 3.2(a): Creative Whack Pack	...37
Figure 3.2(b): Breakdown of design elements: Creative Whack Pack	...37
Figure 3.3(a): Thinkpak	...38
Figure 3.3(b): Breakdown of design elements: Thinkpak	...38
Figure 3.4(a): Drivers of change cards (pack)	...39
Figure 3.4(b): Drivers of change cards (single card)	...40
Figure 3.4(c): Breakdown of design elements: Drivers of change cards	... 40
Figure 3.5: Process Documentation – From goals to inspiration	...42
Figure 3.6: Process Documentation – Iterating on card shapes and colors	...42
Figure 3.7: Process Documentation – Iterating on shape of card	...43
Figure 3.8: Process Documentation – Card back content layout iterations	...43
Figure 3.9: Process Documentation – Representing different categories in an integrated framework	...45
Figure 3.10: Process Documentation – Iterations for organizing categories	...45
Figure 3.11: Process Documentation – Initial prototype description	...46
Figure 3.12: Process Documentation – Final design layout (single card)	...47
Figure 3.13: Process Documentation – Overview card	...47
Figure 4.1: Converting essay level content analysis data into simple concept map	...60
Figure 4.2: Converting essay level concept maps to aggregate concept map	...60
Figure 4.3: Group concept map plots for educational background (2 groups) and experience (3 groups)	...64
Figure 5.1: 18 Skills of Whole Systems Design	...71
Figure 5.2: Final WSD card design layout (single card)	...72

LIST OF TABLES

Table 2.1: Select vocabulary for systems phenomena	...13
Table 2.2: Whole systems designing (WSD) skills – Systems theory	...18
Table 2.3: Whole systems designing (WSD) skills – Design Thinking	...19
Table 2.4: Whole systems designing (WSD) skills – Change leadership	...20
Table 3.1: Outline of Design Approach	...32
Table 4.1: Overview of inter-coder reliability	...58
Table 4.2: Sample result of content analysis for one student	...58
Table 4.3: Data preparation for Kruskal-Wallis Test	...59
Table 4.4: Correlation matrix of aggregate concept maps for all 60 students with each other	...61
Table 4.5: Overall ED membership matrix	...61
Table 4.6: Individual ED-Design membership matrix	...61
Table 4.7: Kruskal-Wallis Test Results	...63
Table 4.8: QAP Test Results	...6

CHAPTER 1

INTRODUCTION

DESIGN APPROACH IN AN ERA OF COMPLEXITY

“Human societies are everywhere complex, for living at peace with ourselves requires a vast multiplicity of rules.”

– Isaac Asimov (1988), American Author and Professor of Biochemistry.

This thesis is sparked by reflection on a very old idea - that the collective physical world around us, our life, is not really designed. It takes shape gradually, as individuals, communities and generations try to solve problems by taking immediate advantage of what they consider to be opportunities, to continually improve the human condition. Therefore change unfolds in a series of interconnected evolutions of relationships and ideas. Understanding how to “design” change on a systems level then, requires tools and understanding that connects multiple levels and skill sets.

This problem is very relevant to many fields like physical science, organizational behavior, information science, systems science, economics, environmental policy, health policy and educational policy. These fields are devoting their efforts to improving the human condition by designing, engineering, planning or governing. Since this work is not concerned with the specific characteristics of each of these fields, but rather with their general underlying patterns, connections and relationships, the general label used is “complex systems”. It should be emphasized that “complex systems” denotes any plausible human-artifact system and, therefore, also includes all efforts made to understand the problem, prepare to make decisions and

implement the solution. Any attempt of improving the human condition, is an act of “complex problem solving” or “whole systems designing” (WSD).

The reason so much effort is being put in complex problem solving is because human society, in its pursuit of progress, has disrupted the natural world. As the 18th century American naturalist and diplomat, George Perkins Marsh wrote in his book *Man and Nature* (1864) “Man is everywhere a disturbing agent. Wherever he plants his foot, the harmonies are turned to discords ... Of all organic beings; man alone is to be regarded as essentially a destructive power.” The collective impact of human society is proving to be self-destructive and unsustainable. To build a sustainable world, we need to reset the default setting of our mindsets. It is crucial to create a shared set of simple rules that empower individuals to act and together build upon each other resulting in collective growth. Liz Coleman, president of Bennington College eloquently expresses this concern in her TED talk ‘A call to reinvent liberal arts education’ as

“There are no excuses ... it would take a radical rethinking of basic assumptions, beginning with our priorities. Enhancing the public good becomes a primary objective. The accomplishment of civic virtue is tied to the use of intellect and imagination at their most challenging. Our approach to authority and agency reflect the reality is that no one has the answer to the challenges facing citizens in this century and everyone has the responsibility for trying and participating in finding them.” (Coleman, 2009)

The biggest barrier to the complex challenges of our time is our traditional silo’d approach to problem-solving. While disciplinary diversity develops the expertise needed to solve specific problems, it can also result in rigid mindsets. There is a need to rethink our design

approach. *The first challenge is to understand the process of complex problem solving. In other words, if change takes place through multiple small acts of intentional design, what elements of this process make it holistic?*

Understanding and implementing this change is a multi-dimensional task. No single trade or field of study can claim to have the complete solution. A multi-disciplinary approach is required for complex problem solving. Analytical reasoning provides the capacity to measure and discriminate between the core purpose and peripheral activities. Design, being the art of creating and meaning making, provides the much needed complement of thought translated into action. In this process, the team continuously faces moral and ethical dilemmas. Accomplishing this task requires balancing the pursuit of intellectual excellence with development of empathy towards others. Tapping into the “whole person” (Danko, 2003) is at the heart of what it takes to design change – intellectual, emotional, moral and social. Models that connect these mutually dependent approaches (rather than divide them into isolating expertise) need to be designed. *The second challenge is to provide a tangible model that allows an individual to comprehend and experience this collective set of skills to facilitate whole systems change.*

The success of such a model, in turn, rests on whether tomorrow’s problems solvers are educated and equipped to comprehend multiple views and levels of complexity. Recognizing the capacity of universities to facilitate this process, David Orr (2002) wrote: “Colleges and universities have a moral stake in the health, beauty and integrity of the world our students will inherit. They have an obligation to provide the students with tangible models that calibrate our values and capabilities – models that they can see, touch and experience.” It is the administrators’ responsibility to empower their educators to create an atmosphere that change the thought process of individual students.

There is a need for talented individuals to turn their attention to this unstructured world of complex problems. Education intended to nurture whole systems designing skills must cultivate collective empathy as well as personal understanding which requires individuals to develop both an inward comprehension of the complex problem solving process in principle and an outward experience of the whole systems designing skills in practice. *The third challenge is, therefore, to figure out what kind of educational methods and tools are required to achieve the objective of (a) teaching and (b) measuring whole systems designing skills.*

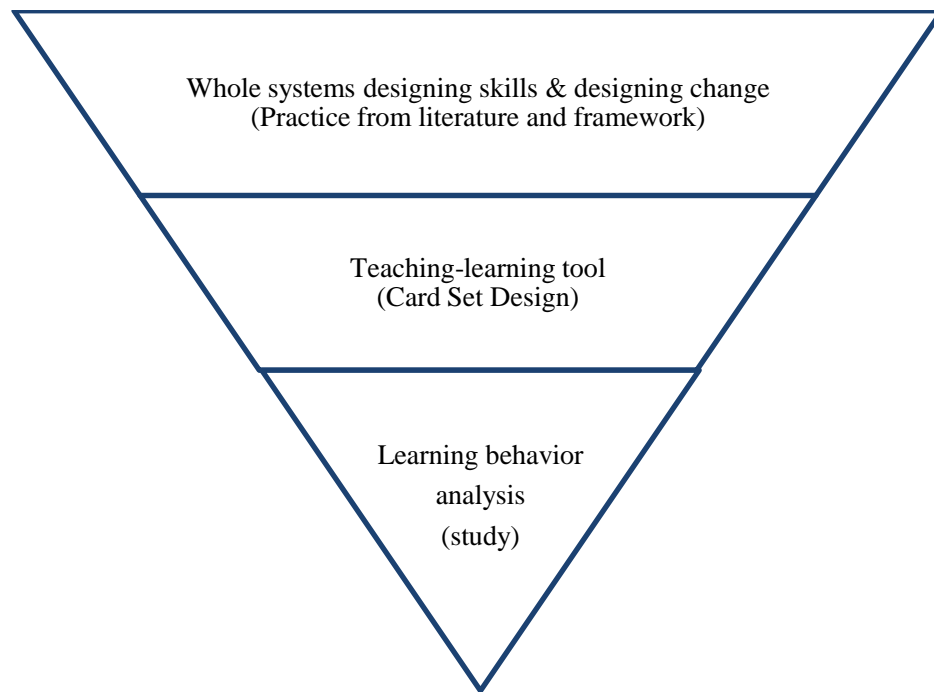


Figure 1.1: Summary of research exploration.

This thesis explores ways of addressing these three challenges. In Chapter 2, the literature for systems theory, design thinking and leadership will be reviewed from the perspective of problem-solving process, in order to identify, integrate and present the key skills of whole systems designing. Reflecting on these skills, a three-layered theoretical framework is will be

presented that links complex systems to underlying patterns of sustainable change. Chapter 3 discusses the design approach for development of a teaching tool – the ‘Whole Systems Designing Card Set. Specifically, the goals, design choices and focus group results will be presented. The goal of the card set is to help educators facilitate the learning of WSD skills. Chapter 4 will present a classroom case study that explores the preferential learning behaviors of individuals based on their problem-solving inclinations using content analysis and network analysis. This chapter will detail the research methodology used and offer results and interpretations to suggest advanced teaching-learning strategies. Finally, Chapter 5 will summarize the complete study and discuss the scope for future work.

The realization that the root of these challenges is conceptual is important because it reveals the author’s own bias for approaching whole systems design from the perspective of design education - learning and skill building. As a cross-disciplinary design researcher, the author is concerned with the conceptual development of problem-solvers, and convinced of the role of ‘whole systems change’ in societal problem solving. Understanding the structure of social change and being able to take the whole systems view in the process of problem solving is the lever that can cause a big shift in our design approach.

CHAPTER 2

LITERATURE REVIEW: UNDERSTANDING WHOLE SYSTEMS DESIGNING

This chapter reviews literature from the intersection of systems theory, design thinking and leadership specifically from the perspective of problem solving process to identify the key skills of whole systems designing. First, the criteria for selecting the literature are explained. Because the problem solving process uses similar terminology to mean different things in various fields, this literature review pays particular attention to understanding the core argument and relating these concepts. In addition to presenting the whole systems designing (WSD) skills, this chapter introduces an emerging framework for approaching whole systems change.

2.1 IDENTIFYING KEY SKILLS OF WHOLE SYSTEMS DESIGNING

Boote and Beile (2005) caution that researchers must take extra precaution where literature review is concerned because of the often “messy” and complicated nature of social problems. They write that the literature review is a way to not only “learn from prior research on the topic”(p.3) but that it should “result in a ‘progressive problem shift’ that yields a new perspective on the literature with more explanatory and predictive power than is offered by existing perspectives”(p.6). They built on Hart’s (1998) criteria and developed a 5-category scoring matrix (Boote and Beile 2005, p.7) for rating literature reviews. This matrix (see appendix B) includes (1) coverage, (2) synthesis, (3) methodology, (4) significance, and (5) rhetoric. These criteria were chosen for this literature review because they promote an important notion: that the literature review (or any problem-solving process) should be guided by some transparent method which, once applied, would lead any reasonable person to similar

conclusions. As the focus of this chapter is on identifying the key skills of whole systems designing only the first two criteria coverage and synthesis are used.

2.1.1 COVERAGE AND SYNTHESIS CRITERION

A good literature review doesn't only discuss the literature included and excluded but also clearly justifies the criterion for inclusion and exclusion of literature – i.e. coverage. (Boote and Beile 2005, p.8). Whole systems designing (WSD) is a conceptual process that crosses many fields and disciplines and has multiple interpretations. In order to connect the wide variety of problem solving approaches arising from different fields, stripping the problem solving process down to a core group of constructs will help one identify the fields of study which give maximum insights in the process of WSD.

Problem solving as reasoning (equation 1) is fundamentally distinct from problem solving as designing (equation 2).

$$[\text{WHAT} + \text{HOW}] = \text{RESULT} \quad \dots \text{equation 1}$$

$$[\text{WHAT} + \text{HOW}] \rightarrow \text{VALUE} \quad \dots \text{equation 2}$$

Reasoning is used to predict (deduction) or to explain (induction) phenomena that already exist in the world. In deduction the 'result' is unknown while in induction the 'how' i.e. the working principle is unknown (Roozenburg, 1995; Dorst, 2010). Designing at its core is an act of creating valuable new things which align and serve a purpose within a larger system. This 'value', unlike the 'result', changes based on the approach ('what' and 'how') of the design team. This study focuses and expands on problem solving as an act of designing.

Revisiting the definition of WSD from chapter 1 -whole system designing is implementing improvement in complex systems by the continuous process of problem solving.

Implementing improvement conceptually refers to the aspired ‘value’ in the above equation. In this equation, it is implicit that improvement is continuous and in the context of a complex system. In order to understand this larger causality as well as generating and maintaining knowledge within the system, the WSD equation is modified to:

$$[\text{WHY} + \text{WHERE}] + [\text{WHAT} + \text{HOW}] \rightarrow \text{VALUE} + \text{LEARNING} \quad \dots \text{equation 3}$$

The above equation infers that WSD requires three sets of functional skills – (1) Recognizing the preexisting pattern within the complex system (Why + Where); (2) creating a new pattern that reformulates and suggests a direction towards an improved system (What + How) and (3) performing all tasks necessary for the value to be delivered and lessons learned to be disseminated throughout the system (\rightarrow Value + Learning). The need of such a multi-functional approach has already been recognized by many fields including ecology (Levins, 1998; Orr, 2002), design (Danko, 2003; Buchanan, 1992), engineering (Jackson, 2010), globalization (Appadurai, 2001) and innovation (Gann and Salter, 2001). Based on this, the scope of the literature review was narrowed down to three fields of study. First, ‘systems theory’ which gives insight into the structure and characteristics of complex systems; Second, ‘design thinking’ which explains the creative exploration and solution based approach of designers and third, ‘change leadership’ which delves into the characteristics of project management and organizational learning.

A simple google search of the terms ‘systems theory’, ‘design thinking’ and ‘change leadership’ gives us 0.86, 0.93 and 0.82 million results respectively. In each of these fields of study, there exist one or more subareas of scholarship. All three fields are inappropriately large and a comprehensive literature review is impractical. To keep the topic manageable, the next

criteria for inclusion was popular and peer reviewed works on topics at the intersection of problem solving process or skills with one of these three fields.

Given the scope of a master's thesis, the author had to make pragmatic choices around the works included for this study. Hence, the literature review started with 10 popular works from these fields including Meadow and Wright's 'Thinking is Systems' (2008), Simon's 'Sciences of the Artificial' (1981) and Senge's 'Fifth Discipline' (1990). The final criteria for inclusion were the network of citations created from these works. Numerous other popular and peer reviewed works were identified based on (1) the citing author's comments on the publication and (2) the bibliographical information. This approach of linking one publication to another through references is central to scientific practice.

Synthesis, the second criteria of Boote and Beile (2005), clarifies and resolves inconsistencies and tensions in the literature. They specify 6 sub criteria and a three point scale (see appendix B).

- a. Distinguish what has been done in the field from what needs to be done
- b. Place the topic or problem in the broader scholarly literature
- c. Place the research in the historical context of the field
- d. Acquire and enhance the subject vocabulary
- e. Articulate important variables and phenomena relevant to the topic
- f. Synthesize and gain a new perspective on the literature

With these literature criteria as a guide, the broader literature of the intersection of problem solving process with systems theory, design thinking and change leadership will be reviewed.

2.1.2 BROADER CONTEXT OF THE FIELD

Systems' thinking is an idea that spans across many fields and disciplines and is interpreted in many different ways. Midgley's (2003) four-volume collection (97 papers), Francois' (2004) two-volume Encyclopedia and Schwarz's (1996) map on "Some Streams of Systemic Thought", give a breadth of the systems literature. The observation of systems phenomena began nearly 2600 years ago with Lao Tsu, who in the 'Tao Te Ching' (1972) described the first system of forces of yin and yang. In his famous book 'The Tao of Physics', Fritjof Capra (2000) summarized the similarities between modern sciences and Taoist philosophy. Formally, systems theory was introduced by biologist Ludwig von Bertalanffy (1969) in his seminal work on open systems and general systems theory. He writes, "Any attempt to summarize the impact of 'systems' would not be feasible". Cabrera (2006) suggests that the vast Systems literature can be divided into two distinct kinds (1) Knowledge about systems which explains the observed systems phenomena in context of specific field and (2) Systems thinking which explains the underlying mindset or cognitive pattern. From the perspective of problem solving it is crucial to identify pre-existing patterns or general systems phenomena within a complex system. Systems phenomena can be derived primarily from the knowledge about systems literature, which distills systems phenomena and illustrates their application in settings like - an organization that focuses on managing social complexity (Ivanov & Ackoff, 1973; Senge, 1990 & 1994; Wheatley, 1999), ecology which focuses on population dynamics (Capra, 1990, 1997, 2000 & 2002; Stone & Barlow, 2005; Meadows, 2008), economy, which talks about non-linear outcomes (Gladwell, 2000; Hawken, 2010) or mathematics, which studies synchronization of dynamic systems (Strogatz, 2003).

Banathy (1996) and Buchanan (1992) discuss the various definitions of design and design related disciplines. They conclude that the multiplicity of design definitions convey the notion that design is practiced by many professions in various ways and is applied to different contexts. The first mention of design as a way of thinking can be attributed to Herbert Simon's 'The science is of the artificial' (1981). McKim's process of visual thinking positions design as a whole-body "way of doing" (Faste, 1994). Nigel Cross (1996, 2001, 2007 and 2011) and Kees Dorst (1997, 2006 and 2010) have been major contributors in the recent times. Christoph Meinel and Larry Leifer (2011) in their book 'Design Thinking' discuss about their five step approach to design thinking. Tim Brown (2008) in his Harvard Business Review article defines Design thinking as, "Design thinking can be described as a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity". Explicitly understanding the underlying skills represented by 'the designer's sensibility and methods' is important for whole systems designing. The steps of a designer's process have been an ongoing and active area of research (Cross, 1982; Simon, 1981; Brown, 2008; Jackson, 2010; Dziersk, 2006). Pourdehnad et.al (2011), who are pushing the boundaries by integrating the systems approach and design thinking discuss the complementarities of these two types of thinkers for solving problems effectively.

Change leadership emerged as a discipline in 1980's driven by leading consulting firms such as John Kotter. His eight step process for leading change (1996) is one of the authoritative works on change management. Organizational learning theory can be traced back to Argyris and Schon (1978). This has evolved into a concept of 'learning organization' by Peter Senge's 'Fifth Discipline' (1990) and Nonaka & Takeuchi's (1995) 'The Knowledge Creating Company'.

Significant contributions have been made in the field of change leadership by Barrett (2003), which focuses on concepts of personal and cultural entropy and Boyatzis (2006), which discusses Intentional Change Theory (ICT) for leaders. Avolio et.al (2009) give a comprehensive summary of various frameworks for leadership like authentic leadership, transformational leadership, servant leadership etc. and their areas of application. In his work 'Leadership for wicked problems', Beinecke (2009) discusses five core leadership competency areas required by leaders to manage change - personal skills and knowledge, interpersonal (people) skills, transactional (execution, management) skills, transformational skills, and policy and program knowledge. Peter Senge (1990 & 1994) in 'Fifth Discipline', Covey (2005) in 'Four traits of great leaders', Nonaka et.al (2000) in their concept of 'Ba' and Margaret Wheatley (1999) in 'Leadership and the New Science' have applied systems theory to organizations and discussed the new role of 21st century leaders as players of the game and not controllers of systems.

In summary, the tremendous scope of the three fields – systems theory, design thinking and change leadership has both positive and negative implications for WSD. There has been a lot of discussion on problem solving skills from each of these fields, individually applied to specific contexts, but no comprehensive framework for understanding WSD by combining these complementary fields has been outlined.

2.1.3 KEY VARIABLES IN THE FIELD

Revisiting the WSD equation, the key variables we explore here are different systems phenomena, steps in the design process and roles of a change leader.

$$[\text{WHY} + \text{WHERE}] + [\text{WHAT} + \text{HOW}] \rightarrow \text{VALUE} + \text{LEARNING} \quad \dots \text{equation 3}$$

One of the primary characteristics of scholarly and popular literature on Systems phenomena is that authors (in particular Boland & Collopy, 2004; Capra, 2000; Forester, 1990; Bertalanffy, 1969; Checkland, 1999; Simon, 1981) propose that a system has three main ideas – part-whole structure of the system, functional relation between its parts and the overall purpose of the systems. Meadows (2008) in her work ‘Thinking in Systems’ has defined a system as a “Set of interconnected elements coherently organized to achieve a goal” (p.11). A list of the various words that convey similar systems phenomenon is shown in table 2.1 (for complete overview see Trochim et.al 2006).

- | |
|--|
| <ul style="list-style-type: none">▪ Dynamic equilibrium, Shifting dominance, Boundaries▪ Elements, components, distinctions, events▪ Feedback loops, Restorative cycles, Interdependence▪ Delays & Oscillations, flows & stacks▪ Constraints of resource & growth, development▪ Resilience, Redundancy, Diversity, Ambiguity▪ Self- Organization, Chaos, Autonomy▪ Hierarchy, Networks, Nested Systems▪ Non-Linearity, Continuum, Sustainability |
|--|

Table 2.1: Select vocabulary for systems phenomena.

To identify actionable key variables, these three main ideas can be broken down and viewed from the perspective of problem solving. Scholars have started to make distinctions to define the

boundaries of the system (Cabrera, 2006; Cabrera & Colosi, 2009; and Meadows, 2008) or problem space (Cross, 1989, 2011) by observing significant events or symptoms. Examining these distinct elements in relation to the whole help identify the causal flow of information. Anderson and Johnson (1997) in their book ‘Systems thinking basics: From concepts to causal loops’ explain the concepts of interdependence within a system and give a step by step process for creating systems maps using delays, stocks, flows and balancing & reinforcing feedback loops (also see Stone & Barlow, 2005). Creating such systems maps helps in observing and analyzing the behavior of the system which ultimately reveals its structure. This structure is also referred to as hierarchy or self-organizing pattern (Raffaelli & Frid, 2010; Wheatley, 1999). A thorough understanding of the structure and behavior or self-organizing pattern of the system points in the direction of the overall purpose or the goal of the system. An expert system thinker understands that a complex system is an emergent entity (Sevaldson, 2011; Capra, 2009; Garud et. al, 2008; Sweeney & Sterman, 2000) caused by underlying set of simple rules (Gell-Mann, 1995), and that the observed resilience (Raffaelli & Frid, 2010; Orr, 2002) and non-linearity is the effect of the interaction of agents within the system trying to follow these simple rules. Capra (2009) emphasizes on emergence by saying “You can never direct a social system; you can only disturb it”. Being able to develop a holistic systems approach i.e. conceptually grasp these systems phenomena will help a problem solver analyze the preexisting pattern and locate problems within the complex system but in order to take action that adds value to the system she will need to explicitly inculcate design skills.

Design thinking is a holistic problem solving process which first forms a solution and then begins to seek constraint. Nigel Cross (1982), Editor of Design Studies Journal writes in ‘Designerly Ways of Knowing’:

“Design thinking is a methodology for practical, creative resolution of problems or issues that looks for an improved future result. In this regard it is a form of solution-based or solution-focused thinking that starts with the goal or what is meant to be achieved instead of starting with a certain problem. Then, by focusing on the present and the future, the parameters of the problem and the resolutions are explored, simultaneously.”

This approach is in contrast with the analytical approach a systems thinker is likely to take, where the problem is broken down into smaller units, constraints are defined and then the solution is explored. Design thinking is an action-framework which takes place under contextual constraints resolution (Rittel, 1972; Cross, 1989, 2011; Dorst, 2010; Sevaldson, 2011).

Several design researchers have proposed an iterative step by step process for designing. Herbert Simon (1969) describes a seven step process – ‘Define, Research, Ideate, Prototype, Choose, Implement, and Learn’ - while the steps for design thinking as followed by the Stanford design school (Meinel & Leifer, 2011) are – ‘Empathize, Define, Ideate, Prototype and Test’. Dziersk (2006) has simplified it into a three step ‘See-Shape-Build’ approach. Cornell’s systems engineering professor, Peter Jackson (2010) in his book ‘Getting Design Right!’ summarizes his eight design steps as - Define problem, Measure need & set target, Explore design space, Optimize design choices, Develop architecture, Validate design, Execute design, Iterate process. Given the number of ways these steps have been categorized it is easy to see that there is no one right way to define the design process, although functional parallels can be drawn. First, the core paradox or competing priorities (Koberg & Bagnall, 1974; Peña & Parshall, 2001; Cross, 2011) are identified to set clear high level objectives for the problem. This includes empathizing with and researching contextual needs and constraints. Then the design team creates an over arching frame or conceptual guidelines (Peña & Parshall, 2001; Dorst, 2010, 2011) that clarify the

assumptions and priorities as they iterate on the solution by prototyping (Guindon, 1990; Teal, 2010; Lidwell et. al, 2010). This step is continued and coupled with a closed feedback loop which involves and acknowledges multiple stakeholders and their biases (Telier, 2011; Cross 2011) till the final outcome is reached. Throughout this process, the designer often reflects upon her actions and behaviors to understand and evolve her implicit approach towards designing. Such a designer represents a professional that Donald Schon (1983) would call ‘the reflector practitioner’. Due to the involvement of multiple stakeholders, this systems designer also needs to develop skills that allow her to manage this process of whole systems change.

The bulk of the work of a change leader is to align and focus the complete problem solving effort. She creates a compelling vision that motivates all the stakeholders and team members in an organization and takes steps to create an atmosphere which enables them to contribute effectively. John Kotter (2011) compares the work of a change leader to that of an engine, “Change leadership is ... associated with putting an engine on the whole change process, and making it go faster, smarter, more efficiently... It concerns the driving forces, visions and processes that fuel large-scale transformation.” This demands creating an organization with self-learning (Boyatzis, 2006) and collective-learning (Nonaka & Takeuchi, 1995; Nonaka et. al, 2000) at the core of its existence. The culture of such a learning organization keeps aside an individual’s narrow self interests and focuses on the whole system (Wheatley, 1999; Barrett, 2006). It fosters a climate of trust and mutual support (Capra, 2009) where change happens through localized actions (Wheatley, 2011; Hawken, 2010). In his book ‘The Fifth Discipline: Art and Practice of Learning Organizations’, Peter Senge (1990, 1994) takes a systems view of organizations to discuss the importance of developing a capacity to clarify ones personal vision, test assumptions and voice disagreements. His five disciplines – personal mastery, shared vision,

mental models, dialogue and systems thinking, provide a great framework for teaching the role of change leaders in whole systems designing.

In review, this section discussed the key conceptual characteristics of systems approach, steps of design thinking and role of change leaders. In the next section, the literature is synthesized from the perspective of whole systems researchers and practitioners.

2.1.3 18 SKILLS OF WHOLE SYSTEMS DESIGNING

The three-part literature review on whole systems designing (i.e. the intersection of systems theory, design thinking and change leadership) requires two additional elements of synthesis to render it useful to practitioners and scholars: (1) An over-arching framework to scholars that bring together these three roles of problem solvers (see section 2.2 for an emerging framework) and (2) Explicit documentation to practitioners for cultivating these abilities. This study treats each of these abilities as skills and organizes them at two levels (1) practices: what one does and (2) principles: guiding ideas and insights (Senge, 1990). Practices are activities that are the primary focus of individuals or groups when they begin to learn a skill. Principles help in understanding the rationale behind the skill and make sense of the practice. The 18 whole systems designing skills i.e. principles and practices, synthesized from systems theory, design thinking and change leadership are presented in Tables 2.2, 2.3 and 2.4 respectively.

NO.	SKILL NAME	PRINCIPLES	PRACTICES
S1	Elements & Events	<ul style="list-style-type: none"> - Distinction - Problem Recognition - Elements influence Events 	<ul style="list-style-type: none"> - Observe events that reveal problems - Identify surface symptoms - Identify all the components and players by talking to /taking perspective of multiple stakeholders - Iteratively expand and bound the problem space
S2	Interconnections & Relationships	<ul style="list-style-type: none"> - Causality - Information Flow - Connections influence Relations 	<ul style="list-style-type: none"> - Observe and examine elements in relation to the whole - Identify delays, balancing and reinforcing feedback loops - Analyze various flows between physical elements - Empathize to understand human needs and relations
S3	Structure & Behavior	<ul style="list-style-type: none"> - Hierarchy - Self-Organizing Pattern - Structures influence Behavior 	<ul style="list-style-type: none"> - Realize the system is more than the sum of its parts - Map all the elements and interconnections and identify archetypes - Observe and analyze behavior over time - Change structure, not just elements to alter function
S4	Leverage Points	<ul style="list-style-type: none"> - Non-Linearity - Non-Redundancy 	<ul style="list-style-type: none"> - Search for insights within the problem that correspond to disproportionate shifts - Identify parts of the structure which maximize desired change and minimize resource requirements - Identify elements and relations which are central or perform the bottle-neck functions
S5	System's Observed Purpose	<ul style="list-style-type: none"> - Holism - Interconnectedness 	<ul style="list-style-type: none"> - Identify the 'goal' seeking tendency by analyzing the behavior - Identify the source of functional resilience - Discover where and how is the diversity and redundancy included
S6	Emergence & Disturbance	<ul style="list-style-type: none"> - Continuum - Functional Resilience 	<ul style="list-style-type: none"> - Get the beat of the system and go for good of the whole - Realize that the resultant system is always the reaction of the existing to the designed - Honor, respect and distribute information, all designs only change the world in small steps

Table 2.2: Whole systems designing (WSD) skills – Systems theory

NO.	SKILL NAME	PRINCIPLES	PRACTICES
D1	Competing Priorities	<ul style="list-style-type: none"> - Core Paradox - Interface between Analysis and Synthesis 	<ul style="list-style-type: none"> - Identify crucial resources and constraints - Distill the subjective and objective responses to look for and make priorities - Set clear objectives with a high level, simplistic and holistic systems view of the problem encapsulated in the goal
D2	Framing	<ul style="list-style-type: none"> - Assumptions - Conceptual Guidelines - Design Objectives 	<ul style="list-style-type: none"> - Recognize and Break the influence of initial design - Surface your team's tacit organizing principles at the outset: Priorities and Contexts - Formulate the problem: Set its boundaries, select specific elements & relations for attention and impose a coherence guiding subsequent moves
D3	Ideation & Iteration	<ul style="list-style-type: none"> - Creativity - Perseverance - Possibilities of Action 	<ul style="list-style-type: none"> - Create a line of exploration that reformulates the existing pattern and suggests a direction towards solution - Use prototypes to explore ideas, elaborate requirements, refine specifications and test functionality - Generate, refine and select concept
D4	Evaluation	<ul style="list-style-type: none"> - Decision Criteria - Feedback 	<ul style="list-style-type: none"> - Balance potential benefits and liabilities of situation - Check against goals of function, form, economy and time - Approach ideas and action plans with fresh eyes - Seek feedback from stakeholders and acknowledge prejudice
D5	Implementation	<ul style="list-style-type: none"> - Action Steps - Process of Growth - Translation into Reality 	<ul style="list-style-type: none"> - Give form to the idea - Have a plan and put the plans into effect - Balance and align the parts with the whole - Examine progress and have contingency plans - Do it together and create short term wins
D6	Reflection	<ul style="list-style-type: none"> - Feedback - Process Insights - Commencement 	<ul style="list-style-type: none"> - Reflect objectively and seek feedback from peers - Take a critical view at the process and compare actions with consequences - Identify behaviors altered or reinforced, skills developed and knowledge acquired - Link insights to further problem solving journeys

Table 2.3: Whole systems designing (WSD) skills – Design Thinking

NO.	SKILL NAME	PRINCIPLES	PRACTICES
L1	Value Creation	<ul style="list-style-type: none"> - Desired Purpose - Vision - Opportunity Recognition 	<ul style="list-style-type: none"> - Identify the Latent potential - Connect this to unfulfilled needs - Understand why and how the value is being added - Define the problem by attempting multiple solution
L2	Value Translation	<ul style="list-style-type: none"> - Impact Measurement - Process of Change 	<ul style="list-style-type: none"> - Measure qualitative & quantitative value generated - Identify & measure effects of unforeseen benefits and problems - Identify stakeholder behaviors altered or reinforced - Understand attitudes towards anticipated change - Review actions to determine how to proceed
L3	Team Learning & Communication	<ul style="list-style-type: none"> - Alignment - Inclusiveness - Collective Intelligence 	<ul style="list-style-type: none"> - Suspend assumptions and surface your defensiveness - Develop capacity to voice disagreements - Encourage dialogues to function as a whole - Acknowledge risks and issues to foster proactive, honest and sensitive discussions - Provide non-threatening Feedback Mechanisms
L4	Mental Models	<ul style="list-style-type: none"> - Openness - Love of Truth - Freedom from Bias 	<ul style="list-style-type: none"> - Question & Test Assumptions individually and collectively - Distinguish Data from Abstract Conclusions based on Data - Balance inquiry with advocacy - Reveal gaps between current and desired culture
L5	Shared Vision & Sponsorship	<ul style="list-style-type: none"> - Commonality of Purpose - Partnership - Mutual Trust 	<ul style="list-style-type: none"> - Build a common vision: share personal visions, listen to others and give freedom of choice - Investigate and acknowledge current reality collectively - Show continued confidence and belief in others ability to change and grow
L6	Personal Mastery & Mentorship	<ul style="list-style-type: none"> - Being - Generativeness - Connectedness - Giving 	<ul style="list-style-type: none"> - Continually clarify your personal vision - Hold creative tension: focus on the results and see current reality - Show commitment, take initiative and make choices - Grow People: coach and help in vision building

Table 2.4: Whole systems designing (WSD) skills – Change leadership

The next step after synthesizing the 18 skills required in the process of whole systems designing is to understand the scope of their application. The next section outlines an emerging framework for whole systems change.

2.2 AN EMERGING FRAMEWORK FOR WHOLE SYSTEMS CHANGE

There are four broad areas in which design is explored (Buchanan, 1992). The first area relates design to symbolic and visual communication, i.e. communicating information, ideas and arguments and abstract concepts with an understanding of emotional connections. The second area emphasizes the design of material objects i.e. problems of construction requiring the integration of engineering and human sciences. The third area focuses on the design of activities and organized services. This area concerns problems of strategic planning involving the meaningful and satisfying flow of human experiences. The fourth area targets the design of complex systems or complete living/learning environments. This last area is concerned with developing adaptive systems that sustain and integrate human experiences with larger natural, cultural, and socio-economic environments.

An over emphasis on these distinct areas of design intervention is part of the reason why problem solvers have been categorized into specific and often silo'd professions like graphic designer, engineer, architect and manager. But a deeper reflection on this categorization exposes the artificiality of the boundaries. Even though these four areas provide specialized solutions for different problem categories, they are inherently connected and contribute towards a continuum of related goals of making the human experience better. Whole system design skills are based on the fundamental process of value creation by designing better human experiences - be it an artifact, an activity or a complex system.

The design of complex systems or complete environments, then, necessitates the design of this continuum of interrelated activities, experiences and materials. For example, an industrial designer is traditionally associated with the design of material objects, but increasingly in today's emerging world of design practice they are exploring the impact of their products across a variety of human activities and have gone as far as creating 'intelligent' products that can adapt to the needs of users in real time. Figure 2.1 offers a hierarchy to understand design in relation to the building blocks of complex systems.

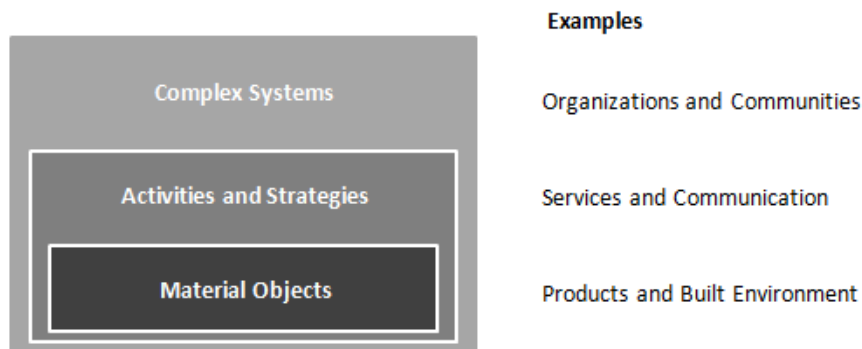


Figure 2.1: Types of design.

Consider a computer system as an example of complex system. It has a number of component parts like CPU, monitor, keyboard etc interact with each other to fulfill the functions of a computer. Although each of these components in itself is a complex system made up of interacting elements like the physical body, the circuit, microchips etc. and each of these parts is again made up of subparts like diodes, resistors, wires and so on which interact with each other. This complex system has a nested hierarchical structure whose components all contribute towards reaching its functional goal of providing a computation system. Simply put, a complex system is a set of interacting components working towards a common goal (Meadows, 2008). In a social system like an organization or global markets the interactive components have two main

types – the material objects (products) and agents that use these objects to perform activities by interacting with each other to achieve a common goal (people). The presence of an agent makes them complex adaptive systems.

Complex systems (computers) differ from complex adaptive systems (social systems) in three fundamental ways – first, in case of failure, a complex systems can be diagnosed deterministically. For example if the monitor is not working, we can diagnose the cause of failure. But in a social system there is no definitive way of diagnosing the problem. Secondly, the next generation of a complex system is a different version, separate from its previous generation. For example, a tablet is a separate device from desktop computer. The shortcomings of the old desktop computer are not carried over to the new tablet device. However, in a social system, the shortcomings of the system are carried forward to the next generation and might not be fully resolved. MIT professor, Noam Chomsky's (2013) explanation of systemic externalities in financial markets highlights the non-deterministic diagnosis and evolution in social systems.

“After the crash, there was the first serious attention by professional economists to what’s called systemic risk. They knew it existed but it wasn’t much a topic of investigation.

‘Systemic risk’ means the risk that if a transaction fails, the whole system may collapse.

That’s what’s called an externality in economic theory. It’s a footnote. And it’s one of the fundamental flaws of market systems, a well-known, inherent flaw, is externalities. Every transaction has impacts on others, which just aren’t taken into account in a market transaction. Systemic risk is a big one. And there are much more serious illustrations than that”.

This is the reason transaction failure is impossible to diagnose deterministically and the post collapse market system doesn’t reset, but has to take steps to recover from the collapse. This indeterministic and evolutionary nature of social systems is source of “wickedness” (Rittel and

Webber, 1967). Finally, in a social system, the design team or the individual problem-solver themselves are a part of the system (one of the agents). Different design teams have different approaches to problems, thereby contributing to the “wickedness” of the situation.

2.2.1 UNDERSTANDING “WICKED” PROBLEMS

Russell Ackoff (1981) used the term “Dilemmas” for problems that are based on the above three differences and cannot be solved within the traditional linear world view. The concept of “wicked problems” was introduced to account for this nonlinearity and has been studied extensively in the literature (see Churchman, 1967; Roberts, 2000; Conklin 2005). Rittel and Webber (1967) in their seminal work ‘Dilemmas in a general theory of planning’ were the first to give a definition of this new class of wicked problems. They defined wicked problems as a “class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing.” and highlighted 10 characteristics of wicked problems:

1. There is no definitive formulation of the problem and every formulation corresponds to a solution. -*Indeterminacy*
2. Every wicked problem is a symptom of another higher level problem. -*Indeterminacy*
3. There is no definitive test for the solution. -*Indeterminacy*
4. Solutions are not true-or-false, but good-or-bad. -*Indeterminacy*
5. An exhaustive list of permissible solutions cannot be created. -*Indeterminacy*
6. Solving a wicked problem has no room for trial and error; every attempt alters the nature of the problem. -*Evolutionary design*

7. The planner has no right to be wrong – They are fully responsible for their actions. -

Evolutionary design

8. There is no stopping rule, it is resource constrained. -*Agency of design team*

9. Every case is essentially unique. -*Agency of design team*

10. There is always more than one explanation for the problem depending on the design team. -*Agency of design team*

The source of wickedness outlined above (author's notes in italics) is based on the three fundamental differences mentioned earlier. The existence of indeterminacy, evolutionary design and agency of design team is the inherent nature of social systems, which supports the central hypothesis that change unfolds in a series of interconnected evolutions of relationships and ideas. A wicked situation - the collective physical world around us - our life, is not really designed. It takes shape gradually, as individuals, communities and generations try to solve problems by taking immediate advantage of what they consider to be opportunities, to continually improve the human condition. In the face of such continuous change how can a design team come up with good solutions?

2.2.2 STRUCTURE OF WHOLE SYSTEMS CHANGE

Acknowledging the presence of these three sources of wickedness, it would be reasonable to conclude that it is impossible to come up with one ideal solution for social problems. In this case, the best thing that a design team can aim for is formulating solutions that are sustainable over a longer term. These solutions, in addition to being implemented through a social process, also have the added responsibility of repairing the larger system around them to make it more coherent and whole. This line of reasoning is similar to Herbert Simon's (1981) concept of

‘satisfying’ - which is one of the cornerstones of Artificial Intelligence i.e. learning algorithms to navigate through complex environments.

Traditionally, problem solvers have been categorized as engineers, managers and designers. Russell L. Ackoff (1981), in his work on operations research asserted that “managers are not confronted with problems that are independent, but dynamic situations consisting of changing problems that interact with each other. In effect, managers do not solve problems but manage messes”. Sevaldson (2009) views the relationship between form and function in architecture as a web of causal interactions instead of a single parameter and calls this new concept “performance-oriented design”. The guiding design intention requires the designers to juggle far more variables and forces than they previously did. A pattern for approaching whole systems change cannot be found by relying on such a traditional categorization of problem solvers. It requires one to look at whole systems designing skills from the lens of *sustainability*.

This study proposes arranging the 18 whole systems designing skills along the y-axis based on *increasing depth of analysis and action* from the perspective of achieving long term sustainable solutions and based on their phase of problem solving (problem phase, solution phase and learning phase) along the x-axis (figure 2.2). Looking at this arrangement from the perspective of the three components of a social system, i.e. objects, agents and system goals, a three-layered pattern quickly emerges (figure 2.3). Each layer maps one of the components to the design skills necessary for creating them – (a) Product Design, (b) Interaction Design and (c) Purpose (or whole systems) Design. This arrangement of 18 skills along 3 layer of sustainable change and three phases of problem solving is called the *Whole Systems Change Framework*.

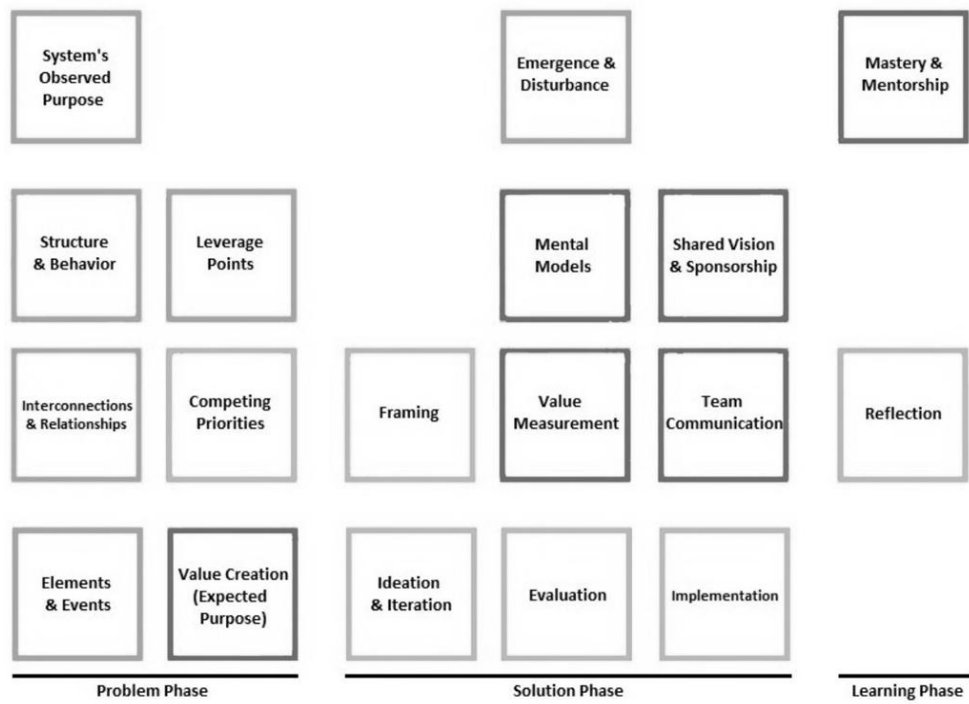


Figure 2.2: Skills arranged from the perspective of sustainability along the y-axis

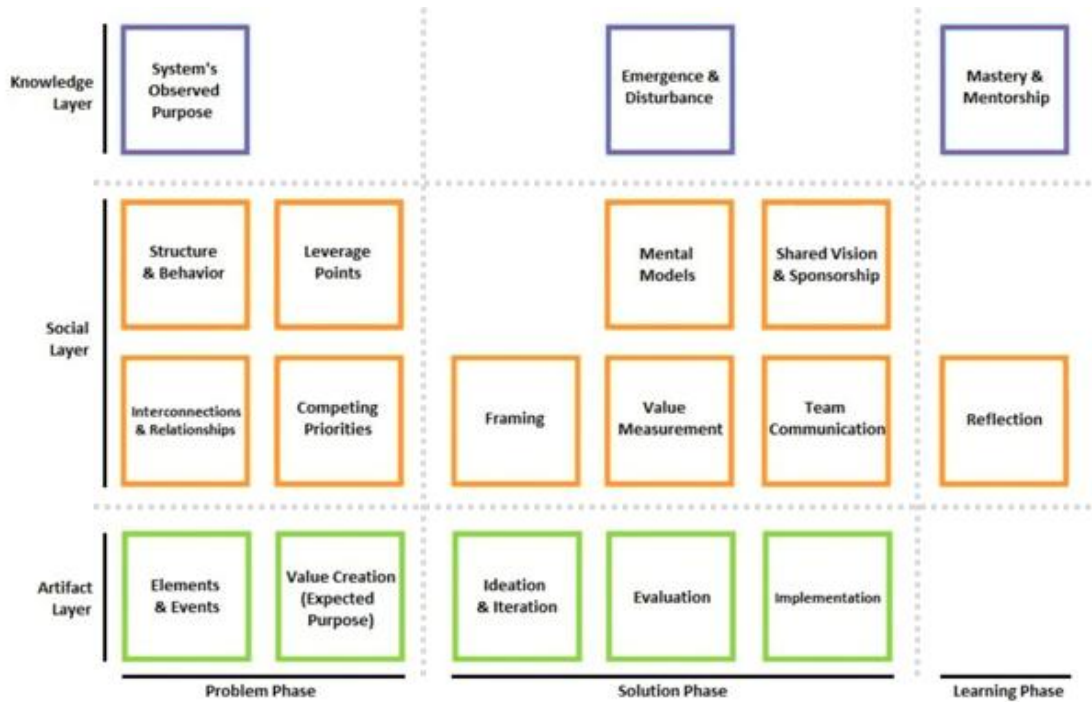


Figure 2.3: Whole Systems Change Framework.

The WSD Framework provides two insights. First, successfully achieving longevity in social systems requires sustaining change along three layers: (a) Artifact layer -where the goal is to design products that are functional and environment friendly, (b) Social layer -where the goal is to design interactions that facilitate communication and create a common culture and (c) Knowledge layer –where the goal is to design learning experiences that promote mastery over the system’s overall purpose. Ignoring or falling short in achieving the goals of these three layers will eventually result in collapse of the social system.

The second very general insight is that sustaining change across these three layers is a continuous and for most part, a simultaneous process, with each successive layer requiring increasing lengths of time. In a social system, products and agents change frequently; the culture changes at a slower pace and the purpose might not change in a lifetime. This is similar to the human body, which completely regenerates every seven to ten years even though specific parts like the skin regenerate much faster than the heart cells.

This phenomenon can be illustrated effectively using the example of an organization.

2.2.4 ORGANIZATIONS - AN EXAMPLE OF SOCIAL SYSTEM

Consider the design of an organization as a social system. The three layers of the framework provide a blueprint of the goals for change in the organizational context: the workplace, the teams and the organization as a whole (figure 2.4). Senge (1990) states, “Leaders who appreciate organizations as living systems approach design work differently. They realize that they can create artifacts like new metrics or formal roles and processes but it is what happens when the people use artifacts or processes that matters”. One can observe that the

insights from the Whole Systems Change Framework not only encapsulate Senge's concept of "leader as designer" but also provide a generalizable approach to whole systems design.

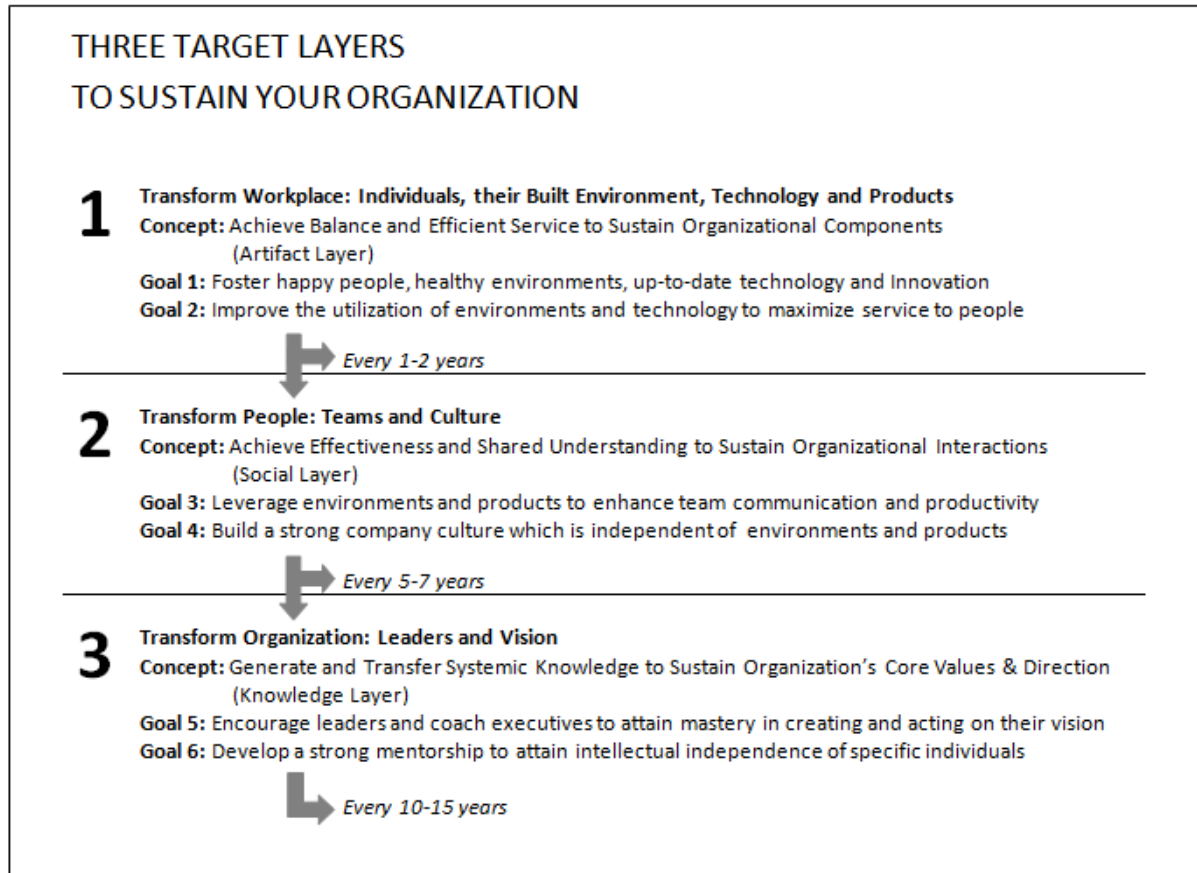


Figure 2.4: Whole systems change framework applied to an organization.

In summary, this chapter assimilates literature from the intersection of 'problem-solving process' with systems theory, design thinking and change leadership to identify 18 whole systems designing skills. Further, it identifies the nature of wicked problems and proposes a three-layered framework for operationalizing whole systems change for practitioners and educators.

As design educators, we want our students to tackle wicked real world problems or what Donald Schon calls "messy but crucially important problems" and hence, it is our responsibility

to develop interdisciplinary collaboration as a competency in these future problem solvers. The next chapter presents the design process for creating a tool which helps teach whole systems designing skills.

CHAPTER 3

DESIGN STUDY: DEVELOPING A TEACHING TOOL

FOR WHOLE SYSTEMS DESIGNING

In the previous chapter eighteen whole systems designing (WSD) skills were compiled and categorized along a matrix of three layers of change (artifact, social and knowledge) and three phases of problem-solving (problem phase, solution phase and learning phase). This chapter outlines the design challenge in developing an interactive learning tool for college level students. The main purposes of the tool are (1) to help a student organize his/her thoughts about whole systems designing into a cohesive framework and (2) to consider future use of this tool in classrooms as a reference tool. The design goals, iterations and the final design solution for this tool are discussed in this chapter. Finally, the tool is evaluated through a focus group study and its methods of use are briefly overviewed.

3.1 OBJECTIVE OF THE STUDY

The goal for a design educator is to impart the whole systems designing (WSD) skills that students will need to master in order to tackle the ‘wicked problems’ they will face in the future. In order to understand WSD well, the students have not only to understand each of eighteen skills individually, in principle and practice, but also how they interact with each other. As the process of wicked problem solving is always collaborative, the tool will help in constructing a shared mental model for the team and act as a starting point in their problem-solving journey. This tool must not only enable students to develop the ability to understand the relationships between WSD skills by analyzing past cases but it must also serve as a process guide for solving

new problems. In summary, the design approach needs to balance study of individual skills with study of their interaction while satisfying the constraints of use by a single student and groups.

3.2 DESIGN APPROACH

The purpose of this step is to develop a teaching/learning tool for whole systems designing and evaluate its effectiveness. This involved a three-phase design approach: (I) Generate Design Goals, (II) Create Design Concepts (Execution) and (III) Evaluate Tool.

<p>Phase I: Design Goals</p> <ol style="list-style-type: none"> 1. Communicate the essence of whole systems designing and empower the student by facilitating self-learning via case analysis and group discussions. 2. Create content that resonates with the students, which engages them individually and in a group and allows them to empathize with systems thinkers, designers and leaders. 3. Facilitate learning via physical interaction, visual suggestion and intellectual stimulation of individuals and groups.
<p>Phase II: Create Design Concepts (Execution)</p> <ol style="list-style-type: none"> 1. Develop design concepts based on design goals. 2. Design a tool to embody each design concept and discuss its various design elements. 3. Iterate to integrate all the design elements and describe final design blue print.
<p>Phase III: Tool evaluation</p> <ol style="list-style-type: none"> 1. Conduct a focus group study to record the student interaction with the tool and solicit feedback on ease of learning. 2. Analyze the insights from the focus group and look for specific modifications.

Table 3.1: Outline of Design Approach

3.3 PHASE I - DESIGN GOALS

Frank Chimero (2012) explains that all design work has 3 common traits: (1) a message to the work which is the central information or idea to be communicated, (2) a tone to the message which is dependent on the audience and the domain of the application of the design, and (3) a format that the work takes i.e. the actual physical product that is created which also includes the choices made around the look, feel and the experience of the product. These three common traits are used for designing this tool because they promote an important notion: that product design or any problem solving process should be guided by some transparent method, which once applied would lead any reasonable person to a similar line of thought. The interplay of the three traits provides a minimal structure to guide exploration while giving enough room for unexpected and creative solutions to emerge. To quote Chimero “Successful design has all three elements – working in co-dependence to achieve a whole greater than the sum of the individual parts” (p.49).

3.3.1 MESSAGE

The first trait of good design is the message. It is the objective of the work and the promise that the work makes. “The value of the work is based on the usefulness of this promise and the designers’ ability to deliver it.” (p.49) The whole system designing tool should explicitly communicate the essence of each of the skill and the impact on a person proficient in those skills. The tool empowers the student by facilitating self-learning via case analysis and group discussions. It also allows a person experienced in using this tool to have a much better structured approach to complex problems. Knowing that each of these skills is a deep complex

concept, the goal is to arouse curiosity towards learning more rather than providing comprehensive conceptual knowledge.

3.3.2 TONE

The second trait is tone that the message takes- it expresses the sentiment and delivers the message to the audience effectively. For design educators the audience is students with varied backgrounds coming to learn design. It is important to create content that resonates with the students engaging them, both at an individual level and as a group while giving them an opportunity to empathize with systems thinkers, designers and leaders.

3.3.3 FORMAT

The third trait of good design is format- the actual physical product and the experience that audience goes through while interacting with the product. Hence, the tool focuses on basic ways a human learns.



Figure 3.1: Cortical Homunculus: How our brain sees our body.

According to research in neurobiology the cortical homunculus (Marieb and Hoehn, 2007) is a representation of how our brain sees our body (figure 3.1). Judging by size humans learn the most when they can use their hands, eyes and tongue. So the whole systems designing tool should not only communicate the complex concepts linguistically but also allow for tactile learning (physical interactions) and visual suggestions to achieve intellectual stimulation. Because WSD is a collaborative process, the tool must also allow for group usage.

3.4 PHASE II - DESIGN EXECUTION

The next step is to prototype a tool design based on the goals. In this section the conceptual approach, inspiration and the design process is described. Finally, the blue print of the whole systems designing tool is presented.

3.4.1 DESIGN CONCEPT

The expected outcome of using this tool is that a student will have a deeper understanding of the 18 skills and their relationships in the whole system designing process as well as their distribution across the three layers (artifact, social, knowledge) and the three phases (problem, solution and learning). Systems' thinking teaches that the structure of a system drives its behavior. In order to get the above learning behavior from students, the tool should be structured such that it allows deep learning of individual skills as well as learning the relationship by permuting different skills.

The proposed tool should function much like a set of cards or a puzzle. An individual card provides insight into the particular skill while multiple cards can be laid out and connected like puzzle pieces to lend a deeper meaning to how different skills interact with each other and

their overall goal in the whole systems designing process. While a more popular alternative would have been a book format, which is easily consumable as people are used to it, the inherent constraint of linearity in the flow of learning goes against the fundamental characteristic of non-linear thinking and design process. This linear flow locks reader into one way of approaching and prevents a deeper understanding of their relationships which is gained by testing out multiple combinations. Furthermore, when doing a case analysis or solving a complex problem the design student or the group can separate out and focus on a few selected bunch of the skills relevant to the situation which is not possible in a book format. The card format also allows design educator to guide the students by zooming in on related skills as well as zooming-out and looking at the broader design landscape. Due to this a configurable card format was chosen for the whole systems designing tool.

3.4.2 INSPIRATION

Three problem solving card sets were used as inspiration to explore format ideas. This choice was based on expert recommendations of popular press tools and is not an exhaustive list.

3.4.2.1 Creative Whack Pack by Roger Von Oech (1989)

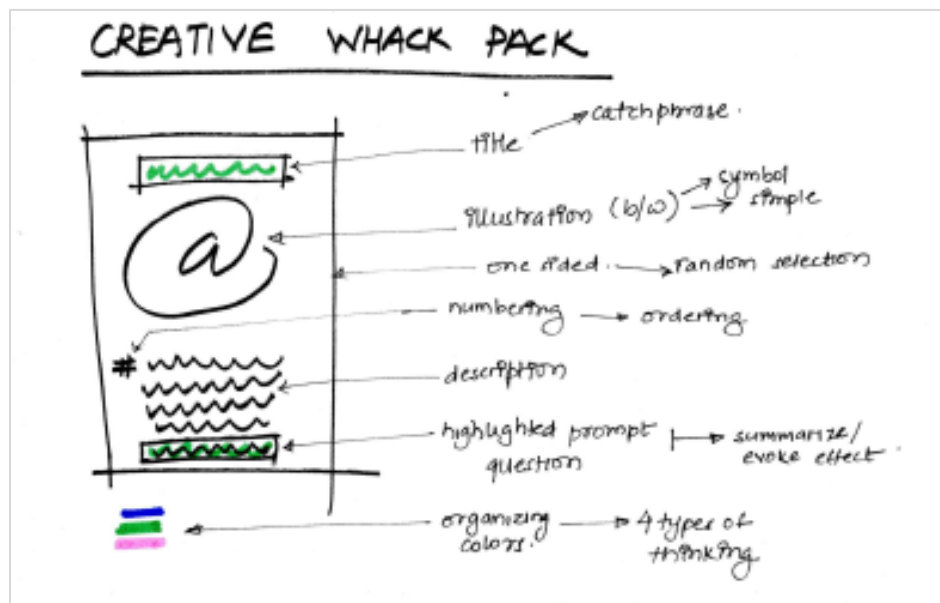
The Creative Whack Pack is a popular press creativity tool designed by Roger Von Oech, author and toy maker. His goal is to "whack" the users out of habitual thought patterns and allow them to look at what they are doing in a fresh way and presents itself as a "creativity workshop in a box." consisting of 64 cards, each featuring a different strategy. Some cards highlight the exploration phase of creative problem solving and suggest places to find new information while others provide techniques to generate new ideas while seeking solutions. A third category of

cards support analysis and decision-making while the fourth category of cards challenges the problem solver to evolve ideas into action.



Figure 3.2(a): (left) Creative Whack Pack.

Figure 3.2(b): (Bottom) Breakdown of design elements: Creative Whack Pack



These cards were assessed for their key design elements which include:

- Simple illustrations to communicate and clarify the idea.
- Use of colors for categorizing 4 types of thinking.
- Highlighted “prompt question” to summarize the main idea.

3.4.2.2 ThinkPak by Michael Michalko (1994)

ThinkPak is composed of 56 individual cards used to create new and innovative ideas created by Michalko a popular press author on the topic of creativity. They can not only be used individually but also with groups, co-workers, teammates, family, children, etc.



Figure 3.3(a): Thinkpak

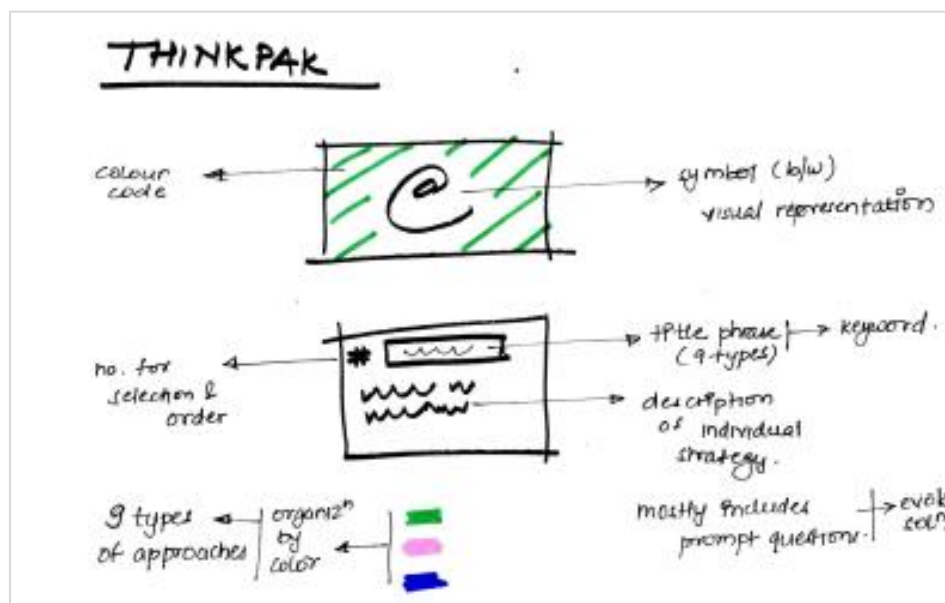


Figure 3.3(b): Breakdown of design elements: Thinkpak

These cards were assessed for their key design elements which include:

- Symbolic representation of 9 type of approaches
- Use of color for organization
- Point-wise description of individual strategy
- Prompt questions that evoke action

3.4.2.3 Drivers of Change cards by Arup Foresight (2009)

The intention is for the ‘Drivers of Change’ cards to act as a trigger for discussion, further research and reflection about the future. Each set of cards is arranged and presented within societal, technological, economic, environmental and political domains that together are known as the STEEP framework. Each card depicts a single driver. A factoid and rhetorical question are on one face, backed up by a brief indication of the breadth and depth of the content on the other face.



Figure 3.4(a): Drivers of change cards (pack)

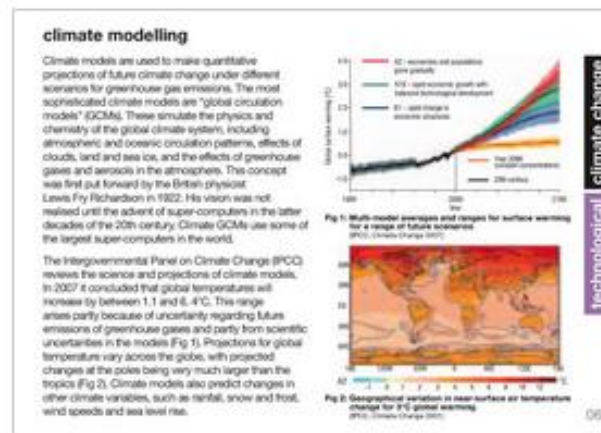


Figure 3.4(b): Drivers of change cards (single card)

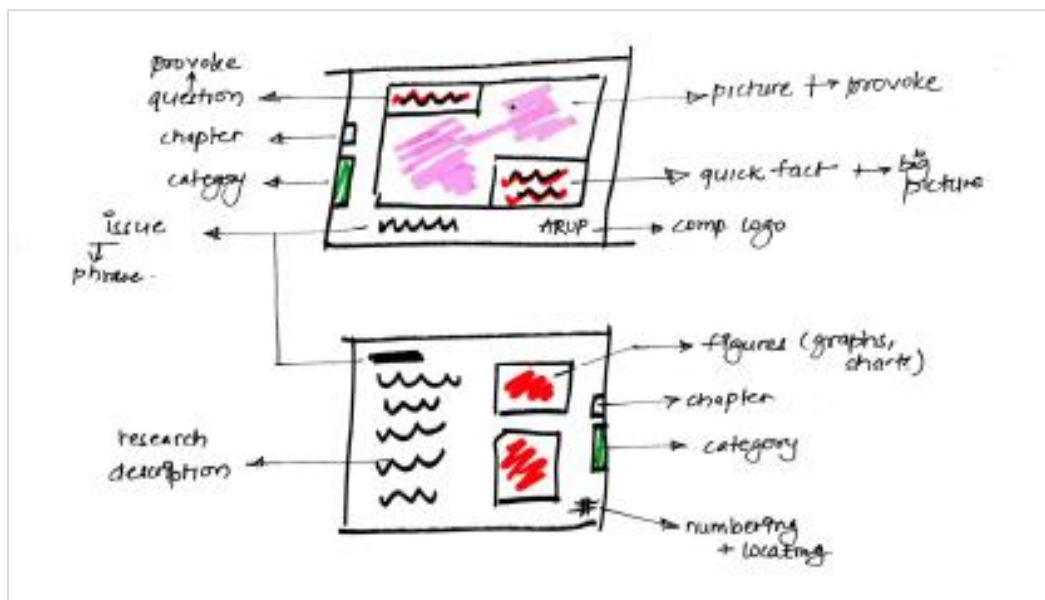


Figure 3.4(c): Breakdown of design elements: Drivers of change cards

These cards were assessed for their key design elements which include:

- Provocative picture.
- Color coded chapters and category markers.
- Indicative figures and illustrations like graphs and charts.

3.4.3 DESIGN PROCESS

This section discusses the design decisions involved in representing each skill on a card and communicating the collective organization of the framework.

3.4.3.1 SINGLE CARD'S DESIGN

Based on the above explorations of three popular problem-solving cards sets, the key design elements for the whole systems designing card set were identified as: (figure 3.5)

- Representative image: A real life image that embodies the principle behind the skill.
- Content distribution: The card contains the skill name as title, a checklist of how the skill is implemented and a collection of key words depicting the essence of the skill.
- Schematic diagram: A simplified block diagram that highlight the role of individual skills during the whole systems design process. These block diagrams form a continuum across all the skills and highlights how each skill relates to its neighbors.
- Layer and phase categorization: use of visual elements like color to distinguish between the three layers of change and three phases of problem solving.
- Use of icons: Simple graphic icons that serve as metaphors to emphasize and anchor crucial ideas and categories.



Figure 3.5: Process Documentation – From goals to inspiration.

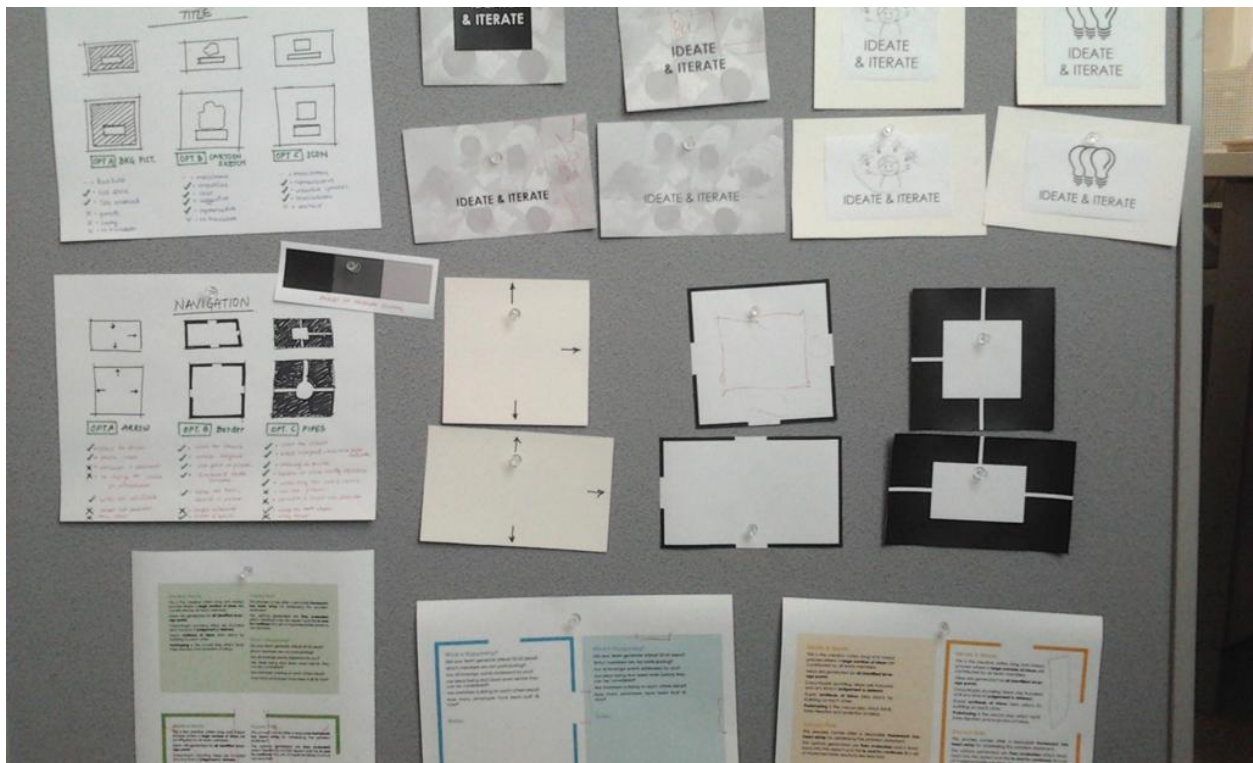


Figure 3.6: Process Documentation – Iterating on card shapes and colors.

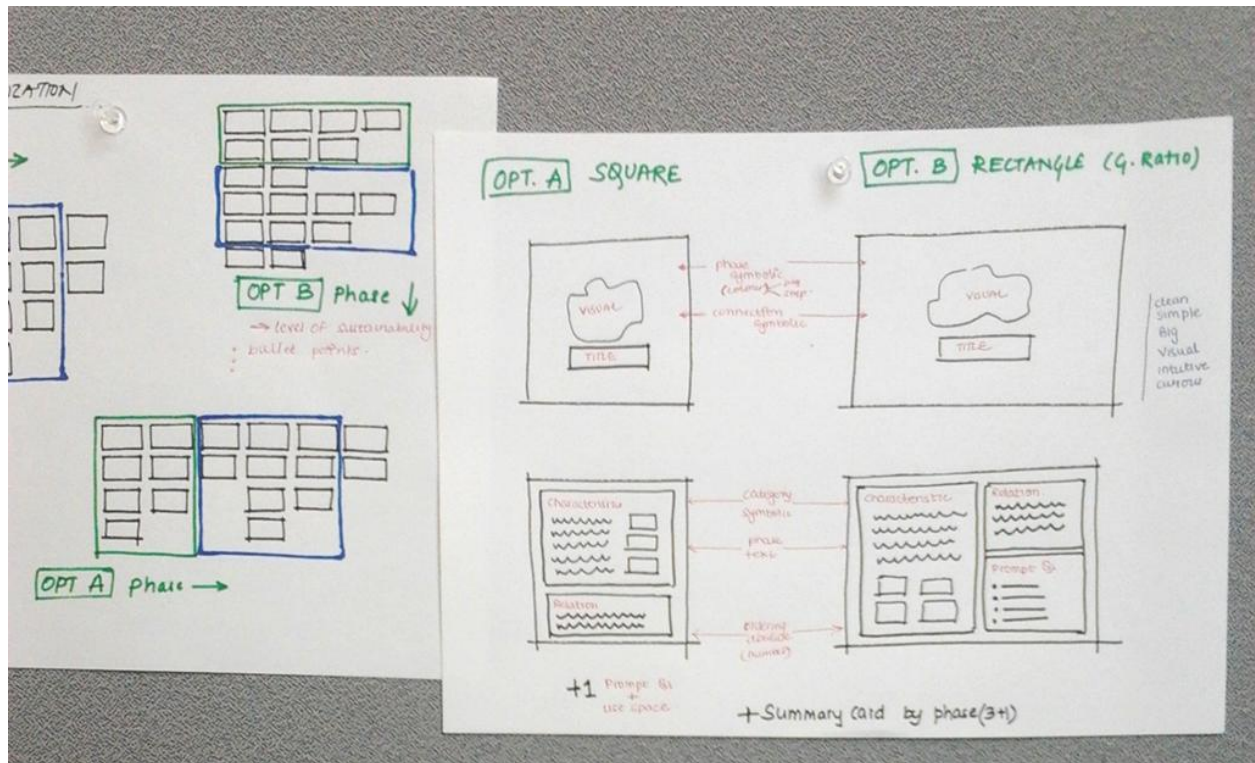


Figure 3.7: Process Documentation – Iterating on shape of card.



Figure 3.8: Process Documentation – Card back content layout iterations.

Other factors and design decisions considered while designing the set of cards:

- Shape of the card: The plausible shapes were circle, rectangle and square. As the framework was categorized along two axes (layers and phases) a symmetrical shape would be preferred ruling out the traditional rectangular shaped card. A square was chosen over a circle as it allows for an efficient utilization of space. (figure 3.6 and 3.7)
- Size of the card: The size was chosen such that it would fit a normal adult human hand, allowing for easy manipulation and exchange within groups. This was balanced out with the largest size possible to make it readable.
- Card background colors: A white background was found to be suitable for reading text and representing schematic diagrams in contrasting colors. (figure 3.6)
- Content layout: A number of different layouts for title, text and schematic diagram were prototyped. A decision to emphasize the practice checklist over principles and schematic diagram was made. (figure 3.8)
- Representative image: Two alternatives for the representative image were prototyped. One, using full color and the other using a grey scale. A decision was made in favor of grey scale image as it provided an opportunity to reflect on the overarching meaning of the image from the perspective of the skill without emphasizing on distracting details.

3.4.3.2 ORGANIZATION OF CARDS IN A FRAMEWORK

The 18 skills can be categorized based on (a) layer, (b) phases in problem solving and (c) field of expertise. It is important to come up with different organizing mechanisms in order to group and study them from these different perspectives. (Figure 3.9 and 3.10)

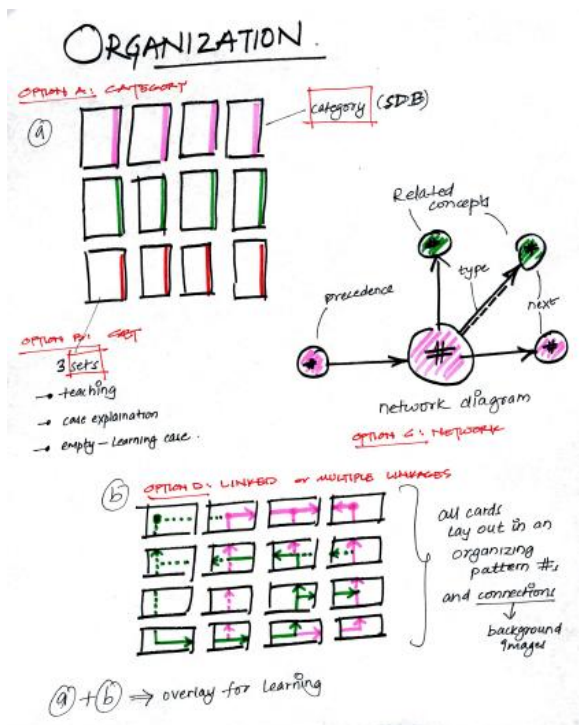
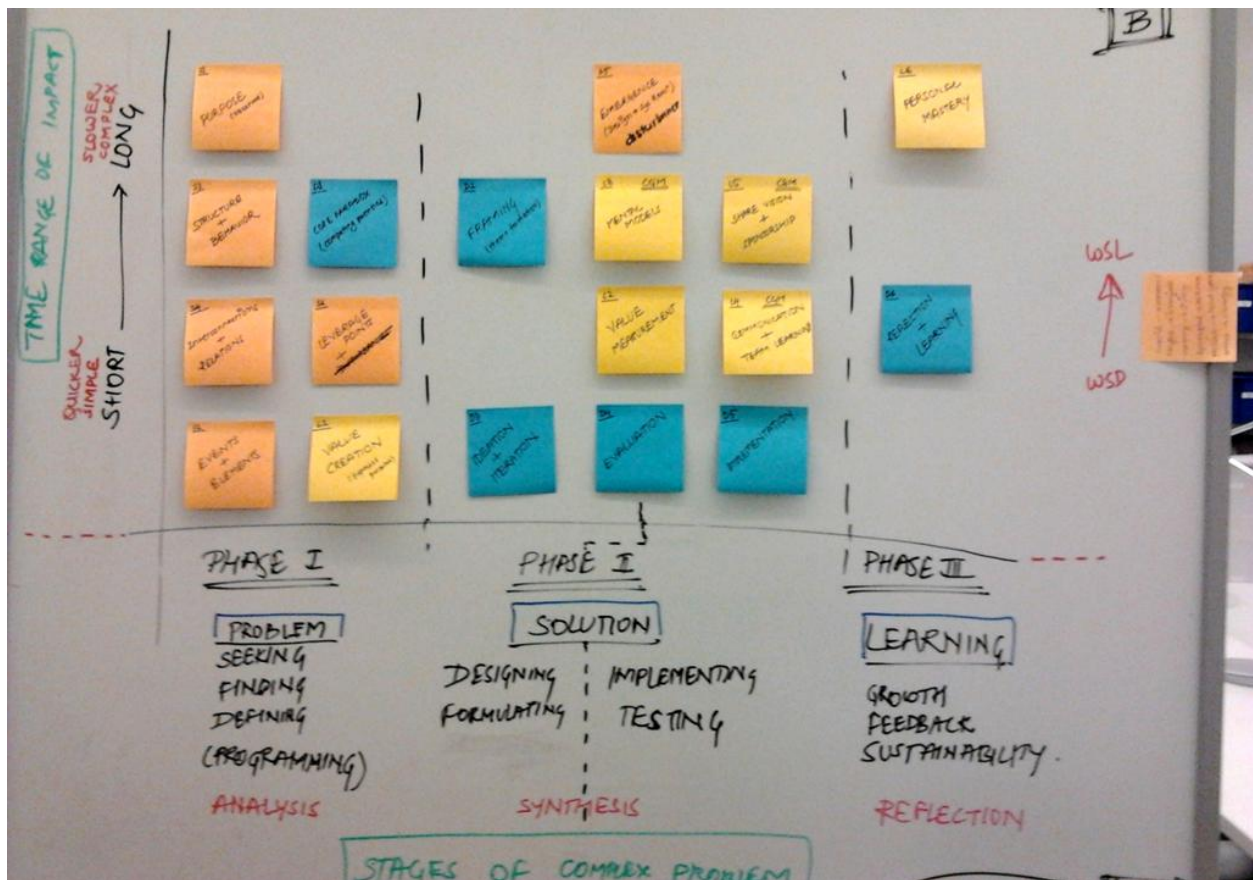


Figure 3.9: (above) Process Documentation – Representing different categories in an integrated framework (Phases along X axis, Layers along Y axis and Disciplinary concepts using color of post it.).

Figure 3.10: (left) Process Documentation – Iterations for organizing categories.

3.4.4 FIRST PROTOTYPE DESCRIPTION

The front side of the card includes the suggestive photograph and the title. The front is also used to show different phases of the process by using shades of gray as the border. The back of the card includes the title, practice checklist and keyword list. The schematic diagram is also shown at the bottom right corner. The type of concept based on the field of expertise is shown just below the title. Again, the three layers are distinguished using different colored borders.

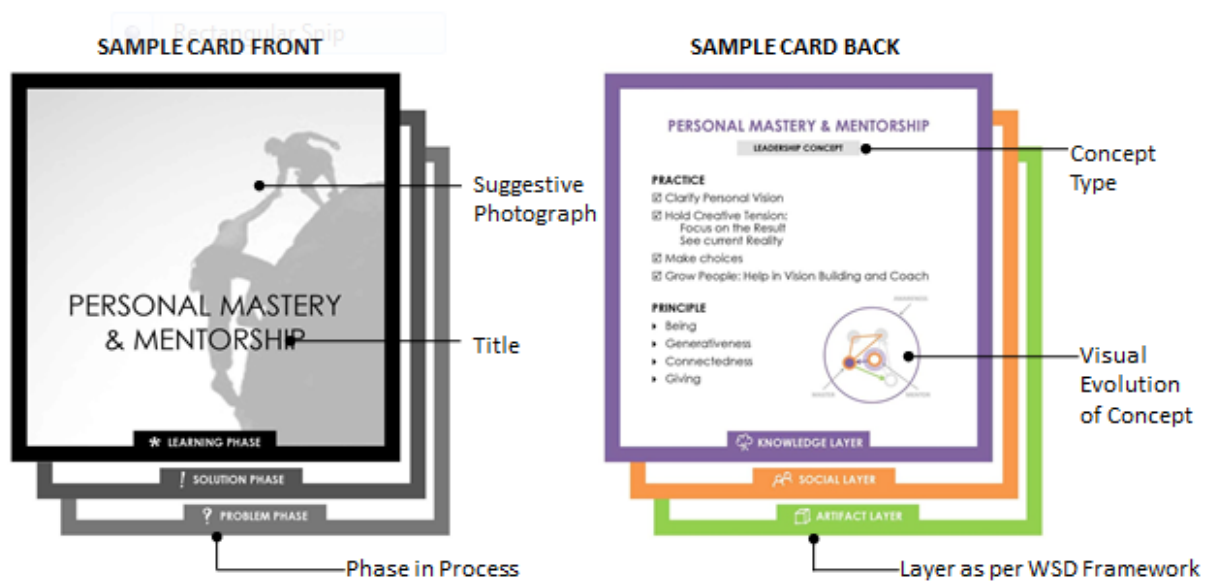


Figure 3.11: Process Documentation – Initial prototype description

On printing this prototype design it was found that it was difficult to maintain a consistent border width on all 4 sides of the card. It was also found that the gray color variation on front side of card representing the problem, solution and learning phase was confusing as it wasn't sufficiently distinct. In a number of cases the grayscale representative image merged with the borders. Based on this feedback, modifications were made to the final design.

3.4.5 FINAL DESIGN LAYOUT

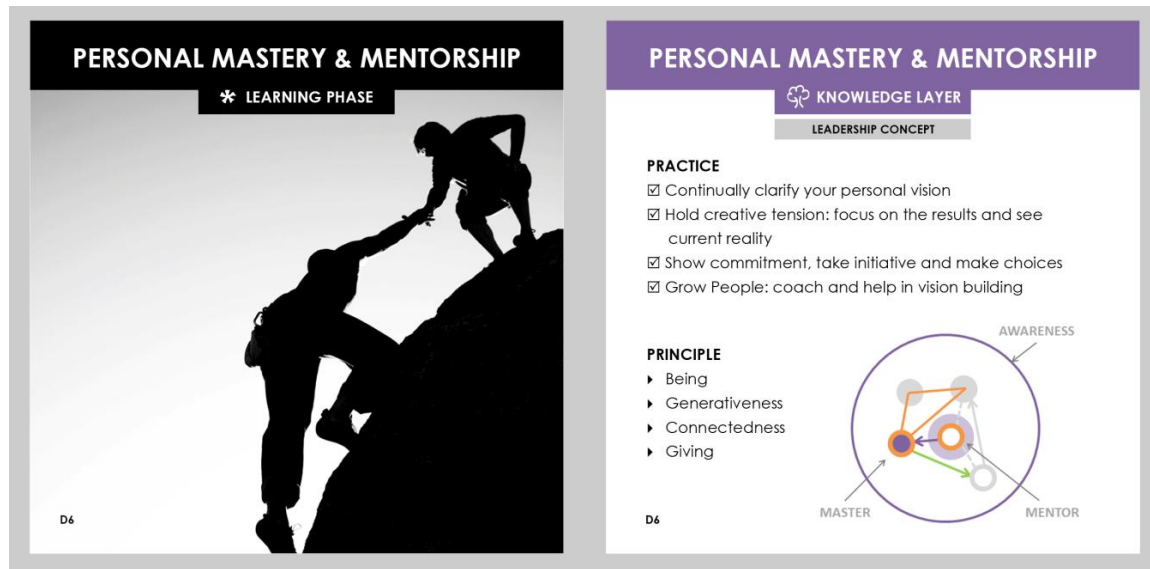


Figure 3.12: Process Documentation – Final design layout (single card)

A total of 20 cards were created: 18 whole systems designing skills, one title card with definition of whole system designing and directions for use, and one overview card with an indexed list of all the 18 skills on the front side and the overall framework on the back (figure 3.13). Appendix A shows the complete set of 20 cards.

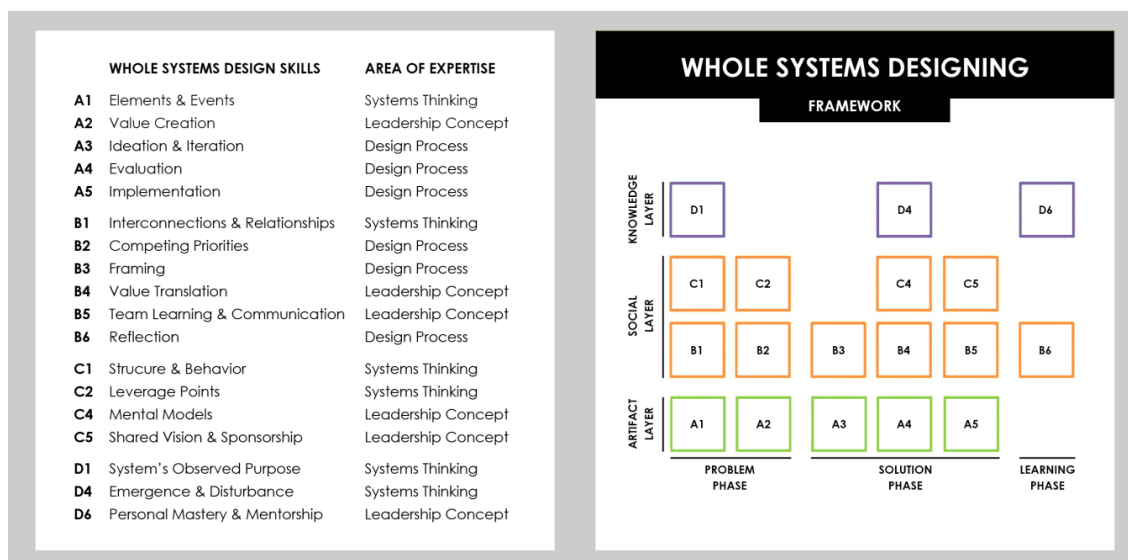


Figure 3.13: Process Documentation – Overview card

3.5 PHASE III - DESIGN EVALUATION

The whole systems designing card set was evaluated by conducting a focus group discussion during the prototype phase.

3.5.1 FOCUS GROUP DESCRIPTION

A focus group discussion was held with 5 students on May 4th 2013. Participants were engaged in one group task using the whole system designing card set. This task involved reflection on the problem solving process of the popular design case: IDEO's Shopping Cart Redesign. Participants provided information in 2 ways - written response and group discussion. The focus group lasted for duration of two hours and a note taker summarized the discussion. The discussion was designed to gather information from the students in regard to the following outcomes:

- 1) To understand the impact of different design elements on the card from the perspective of ease of understanding.
- 2) To understand the use of cards for teaching the 18 skills.
- 3) To understand the use of cards for case analysis.
- 4) To understand the pros and cons of a card format.

Participant Demographics:

- Educational background: Two out of the five were design students and there was one each from Fiber Science, Biology and Human development.
- Grade level: Three out of five were sophomores. Two were freshmen.
- Gender: All five were females.
- All students had previously taken an introductory design course at Cornell University.

3.5.2 PARTICIPANT PERSPECTIVES

This section presents the questions used to gather information about outcomes and summarizes the key themes from consequent discussion.

Outcome 1: To understand the impact of different design elements on the card from the perspective of ease of understanding.

Question 1: What part of the card did the participants look at first and why?

In general, the participants like the cards because the pictures made sense to them and were well explained by their text description. The note taker observed that three out of five participants chose to look at the text descriptions while the other two looked at the picture in the front of the card. One participant who looked at the picture first was found flipping back and forth from picture to text descriptions and later mentioned that the picture helped her get the central idea of the skill and make sense of textual explanation. Another participant who looked at the text first stated “The text descriptions are very inspiring”.

Question 2: Rate each card on a 5 point scale.

- ‘Value creation’, ‘Shared vision & sponsorship’, ‘Personal mastery and mentorship’ and ‘Team learning & communication’ (card A2, C5, D6 and B5 respectively) were the most easy to understand.
- ‘Mental Models’ (card C4) was the most difficult to understand.
- The representative image for ‘Framing’ (card B3) was confusing.

Outcome 2: To understand the use of cards for teaching the 18 skills.

Question 3: How would you use these cards in a classroom for teaching whole systems design?

In general, all participants agreed that having the complete framework to play with made it very easy to break the problem down but also emphasized that trying to learn all 18 skills at once might be unrealistic. One of the participants stated “Giving out the cards in 3-4 smaller sets over time would help the students focus on each step and not get overwhelmed”. Another participant said “People like me who want to be ahead of the class, may want to have all the cards at once so that they can read them beforehand”. Participants also discussed other ideas like

- Having the students to reflect upon and discuss a personal experience relating to the skill they learnt that day after class.
- Providing a list of suggested reading material for further learning of these skills.

Outcome 3: To understand the use of cards for case analysis.

Question 4: How would you envision using these cards for understanding and approaching design problems?

Four out of five participants agreed that the card set would be tremendously useful for solving problems in an interdisciplinary group. One participant stated “It’s better to include people from different backgrounds in the design team”. According to them, when working in groups everyone should have their individual card sets because people may interpret them differently and help create a richer conversation around the problem at hand. They concluded that an additional card set for the group should be used for contributing in organizing the team’s ideas. Even while working in a team, the card set helps to understand the bigger picture while being clear about individual responsibilities. “This helps me put more focus on what factors to consider while designing”, said another participant.

Outcome 4: To understand the pros and cons of a card format.

Question 5: What would you change about the format of the cards to make them more effective?

Generally, the participants thought the card set was pretty and portable. It could be played with, manipulated and moved around anchoring the learning of these skills. They discussed presenting the cards in a book format and came to the conclusion that the linear format of a book would erroneously hint at a sequential process. Several participants commented that it would be frustrating to handle twenty separate cards and they might end up losing a few. They suggested putting a ring on these cards so the cards would also serve as a booklet, “They can then be laid on the desk by removing the ring and can be assembled when you want to read it as a booklet.”

3.5.3 MODIFICATIONS AND RECOMMENDATIONS

It is clear from the responses and discussion that students found the whole systems designing cards useful – particularly in solving real life problems. They wanted the cards to be easier to collaborate over, learn and manage.

- Use a group card set or a big poster showing the framework for better collaboration.
- Teach using an activity which helps the student build the entire framework. To ease learning one of the participants stated, “The set of cards gives a broader perspective of abstract ideas. A lecture might be able to explain each one in more depth but often focuses too much on detail so much so that the *full* picture is unattainable. The *full* picture is vital, in order to understand and wrap your head around concepts. It helps tremendously to be able to play with the cards and physically move them around.”
- Attach a ring to enhance portability and manageability of the card set.

4.6 DISCUSSIONS – IMPLICATIONS FOR DESIGN EDUCATORS

A design educator cares about her students' conceptual understanding, their capacity to work in teams and their ability to communicate complex ideas across disciplinary boundaries. Can the whole systems designing card set help the educators achieve that? According to the feedback from the small focus group, these cards promoted learning by providing an opportunity to engage with each concept and their relationships. They enabled the group to see the big picture and the detail at the same time. Further, the cards promoted learning through collaboration within the group. The card set provided a platform for the group to discuss an existing design case, or approach a new design problem through discussion. They acted as a starting point to launch a discussion about real world (complex) problems by building a shared mental model around complicated design issues.

On the other hand, the cards do not teach about the any of the skills in depth. At best, they give a taste of what the concept behind a skill refers to. The skills are so interconnected that there is no prescribed directionality for learning all the skills, making them difficult to teach. The cards can be used as reference material but cannot substitute human teaching. One of the biggest limitations of this tool is that it is generic. Since each student learns differently, in order to achieve the desired effectiveness of the cards, the educator will need to come up with different strategies. How can an educator be empowered with a playbook of strategies for approaching different types of students?

The next chapter sets up a research study to explore the patterns in learning behavior of whole systems designing skills for different type of students.

CHAPTER 4

RESEARCH STUDY: UNDERSTANDING LEARNING BEHAVIORS RELATED TO WHOLE SYSTEMS DESIGNING

In the previous chapter, the author developed a card set which is a tool for teaching the principles and practice whole system designing. But having a tool is not sufficient as Design Educators face the challenging task of contextualizing and teaching students coming from a variety of disciplines and with different learning styles. This chapter describes the use of network methods for mapping and illustrating the preferential learning behaviors of students. It details the research methodology used and offers results and interpretations from a multi-disciplinary design classroom case-study conducted between August 2012 and January 2013.

4.1 OBJECTIVE OF THE STUDY

The objective of the study is to identify the bias of different groups of students in learning the 18 whole systems designing skills. The learning process of students is affected by a number of factors. The three factors considered for this study, that directly influence a student's learning process are (1) educational background, (2) learning style and (3) experience in school.

First, the educational background which represents the student's academic context – her peers, subjects of study etc. form the student's root perspective on all the skills they learn. It is operationalized based on their major in school and has two groups: Design and Non-Design. Pourdehnad et al, (2011) discusses that design education is predominantly expansionist and synthetic, while non-design and engineering education is primarily reductionist and analytical.

Second, the student's intrinsic learning style is operationalized based on Kolb's theory of experiential learning (Kolb 1984, Kolb, Boyatzis & Mainemelis, 2000). This theory distinguishes students into four groups - Converger, Diverger, Accomodater or Assimilator based on their role in problem-solving. As the purpose of this study is to measure student's learning of problem solving skills, Kolb's theory was chosen over Gardner's (1983) theory of multiple intelligences which proposes seven criteria of intelligence. Kolb's learning style inventory (LSI) (Kolb, 1976) is the survey instrument used to determine a student's learning style.

Finally, a student's experience in school represents her relative familiarity and practice with concepts of problem-solving, which is operationalized by dividing the students into three groups based on their year in school: Year 1 (freshman), Year 2 (sophomore) and Year 3 (junior and senior). This factor can capture the effects of maturity i.e. experience with a wider range of problem solving activities leading to a well formed personal process of designing.

In particular, the study explores three research questions:

1. *Does membership to a group associate with different skills learnt at an individual level?*

This information will reveal an individual student's predisposition to learn a specific set of skills based on the group they belong to. This will allow design educators to create introductory teaching material that is easy to consume for a wider range of students.

2. *Does membership to a group associate with similar concept maps at a group level?*

This information will reveal if students belonging to a group tend to have similar ways of connecting different skills, allowing the design educator to formulate custom strategies for teaching target groups with higher effectiveness.

3. *How the skills are related for groups with similar concepts maps?*

This information can be used to contextualize and scaffold the learning of particularly difficult concepts. Vygotsky's (1978) socio-cultural theory and the notion of Zone of Proximal Development (ZPD) form the basis of "scaffolding". Scaffolding is a process of setting up topic in proximity to topics that the student already knows, thereby making their learning process easy.

The next section describes the research setting and data collected for this study.

4.2 RESEARCH SETTING AND DATA COLLECTION

To explore answers to these three research questions the research setting should satisfy five conditions. First, it should be a course taught with focus on problem solving covering concepts from systems thinking, design process and leadership theories. Second, it should have students from diverse disciplines. Third, it should have a mix of grade levels. Fourth, it should administer open ended qualitative measures to understand the students' problem solving process. Fifth, these measures should be administered at least three times – beginning, middle and end of the teaching period.

To meet the above conditions, data was collected from an introductory design course DEA 1110: Making a difference by Design, offered in fall 2012 at Cornell University. This class taught problem solving and whole systems designing from traditional design process, systems thinking and leadership values. The concepts did not require any background knowledge or expertise on any particular topic. This course used traditional MS PowerPoint lectures, individual/group projects and narrative teaching methods. The class consisted of 78

undergraduate students. Disregarding students with less than 80% attendance, the data for 60 participants (mean 93.7% attendance) was utilized. The data on education background and year in school was collected from the academic records. The distribution of students along educational background is Design (47%) and Non-Design (53%); the distribution for experience is Year 1 (37%), Year 2 (37%) and Year 3 (26%). Kolb's LSI instrument was administered at the beginning of the course and the distribution is as follows: Converging (17%), Diverging (27%), Accommodating (34%) and Assimilating (22%). The course requirement was to write a one page reflective essay based on five different problem solving cases over the entire term. Even though each case allowed the student to reflect on any of the 18 skills, the response was limited to explaining four principles per response. A total of 300 essays were collected (60 participants, 5 essays each) during the term.

4.3 METHODS

4.3.1 CONTENT ANALYSIS

The first task was to convert this qualitative data to quantitative data using content analysis. Content analysis is a social science methodology used to understand the meaning of different forms of subjective communication like texts and phrases in an objective and quantitative manner. The main disadvantage is that it is prone to errors and is very time consuming as it is dependent on the subjective interpretation of the written material. Broad categories or codes are created for classifying the text as there is no theoretical base for creating meaningful relationships in text (Krippendorff, 1980). The success of content analysis relies on consistent coding which was achieved by conducting an in-depth coder training involving a pilot study.

Each essay consists of four bullet points reflecting on a single problem solving principle. So the unit of analysis, i.e. the smallest piece of text considered to report codes, is a paragraph. These paragraphs are coded based on the central idea communicated by the author rather than coding for key words or phrases. This is known as summative content analysis.

“The summative approach to qualitative data analysis is done when researches use a quantifiable methodology to look for certain words or context within the text in order to understand it. It does not provide the researcher with the meaning of the text. Instead it uses the word or context to explore usage. If the researcher stopped at this point the information would be quantitative instead of qualitative. However, at this point the data is then interpreted in order to understand its meaning and the underlying communication of the text making it qualitative. ” (Lombard, Duch and Bracken, 2004)

A pilot study was conducted with 2 coders and 29 essays to create 18 codes corresponding to the 18 skills of whole systems design. This involved teaching the 18 skills to the coders over five 2-hour discussions. The coders discussed their interpretation of the skills with each other giving several personal examples followed by interpreting sample student essays. As a result, two general guidelines were established for the coders that helped improve the inter-coder reliability from 0.522 to 0.79. One, identify the skills that author currently practices or intends to develop. Second, identify skills that the author explicitly mentions as an important part of their personal problem solving process. These guidelines were setup to improve the inter-coder reliability.

The validity of the results of content analysis can only be ensured by achieving high inter-coder reliability. Inter-coder reliability is needed in content analysis as it measures “the extent to which the different judges tend to assign exactly the same rating to each object” (Tinsley & Weiss, 2000). An inter-coder reliability value greater than 0.6 is considered satisfactory. For our data set, 18 inter-coder reliabilities were calculated using Cohen’s Kappa. The mean inter coder reliability for the entire dataset of 300 essays was 0.79 (SD = 0.07).

	All Data	Pilot Data
Number of students	60	29
Number of essays per student	5	5
Unit of analysis per essay	4	4
Total units of analysis coded	1200	580
Number of codes	18	18
Number of coders per code	2	2
Mean inter-coder reliability (Cohen’s kappa)	0.79	0.522

Table 4.1: Overview of inter-coder reliability

	S1	S2	S3	S4	S5	S6	D1	D2	D3	D4	D5	D6	L1	L2	L3	L4	L5	L6
Essay 1	0	0	0	0	0	1	0	0	1	2	0	1	0	1	3	3	0	0
Essay 2	0	0	1	0	0	0	0	2	1	0	0	0	0	1	0	0	0	0
Essay 3	0	1	0	2	0	0	0	2	0	0	0	0	0	1	2	0	1	0
Essay 4	0	0	0	0	0	0	1	2	0	0	0	0	0	2	0	0	1	0
Essay 5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Total	0	1	2	2	0	1	1	6	2	2	0	1	0	5	7	3	2	0

Table 4.2: Sample result of content analysis for one student

Sample result of content analysis is shown in table 4.2. Each column gives the number of times this student was coded positively for writing about a whole systems designing skill in the 5 essays. The last row gives the aggregate for the student. For example, this student wrote about skill L3 7 times and skill D2 6 times, and never wrote about skills S1, S5, D5, L1 and L6.

4.3.2 STATISTICAL ANALYSIS

We use standard statistical hypothesis testing methods for research question 1 and network methods to answer the research question 2 and 3. All analysis was conducted using R Studio v0.98.

1. Does membership to a group associate with different skills learnt at an individual level?

In order to find the difference in learning skills at an individual level based on the group they belong to, an ANOVA test was applied between the aggregate student results from content analysis and the three factors that affect learning (i.e. educational background– Design & Non Design, learning style– Accomodators, Assimilators, Convergers & Divergers and experience– Year 1, Year 2 & Year 3). Kruskal-Wallis rank sum ANOVA test was chosen as the data set violated the normality assumption of standard ANOVA test (see Corder and Foreman, 2009 for details). Table 4.3 shows sample data prepared for Kruskal-Wallis ANOVA test. The test was conducted 54 times, once between each of 18 skills and 3 factors.

	Ways of Grouping			Skills																	
#	ED	LSI	YR	S1	S2	S3	S4	S5	S6	D1	D2	D3	D4	D5	D6	L1	L2	L3	L4	L5	L6
1	ED1	LSI1	Y1	0	1	2	2	0	1	1	6	2	2	0	1	0	5	7	3	2	0
2	ED1	LSI1	Y2	2	7	1	1	1	1	0	7	1	0	0	2	1	6	3	1	4	3
3	ED1	LSI2	Y2	0	1	2	2	0	1	1	6	2	2	0	1	0	5	7	3	2	0
4	ED2	LSI3	Y1	3	3	2	0	2	1	0	5	0	0	0	1	0	4	2	2	2	1
5	ED2	LSI4	Y3	2	1	1	1	0	1	3	2	5	3	1	0	0	6	4	1	1	1
.
.
60	ED2	LSI3	Y1	0	0	0	1	0	4	2	2	0	1	2	2	0	1	1	6	3	2

Table 4.3: Data preparation for Kruskal-Wallis Test

2. Does membership to a group associate with similar concept maps at a group level?

These group level patterns were found by correlating the similarity of aggregate concept maps of any two students with their membership networks using a five step process. First, concept map was created for an individual student using content analysis data from just one essay. This was achieved by assigning unit tie strength between all skills (as nodes) that co-occur in one essay i.e. a complete graph made with skills having non-zero values as nodes. (See figure 4.1)

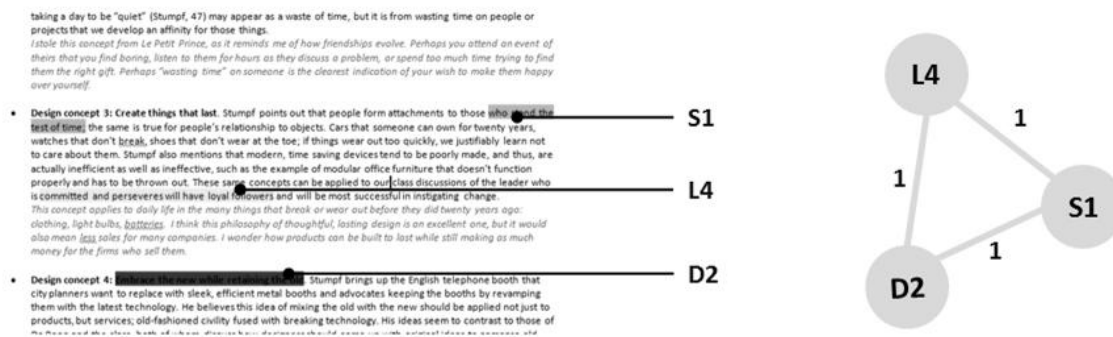


Figure 4.1: Converting essay level content analysis data into simple concept map

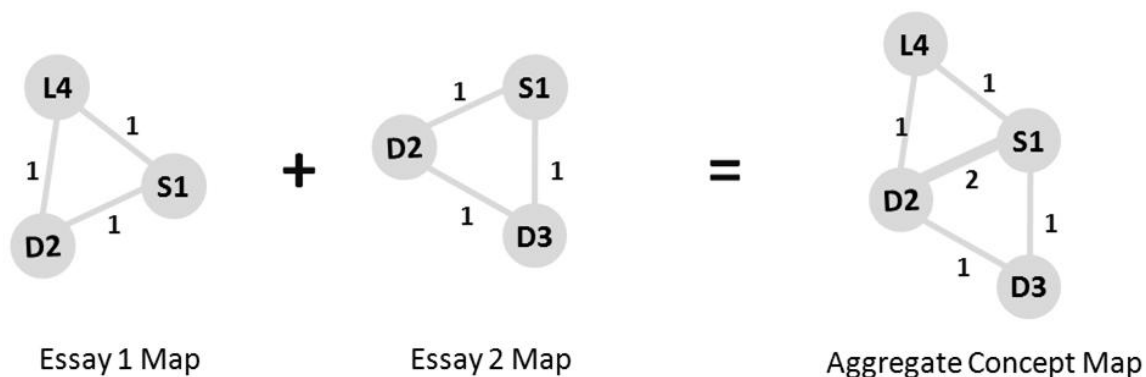


Figure 4.2: Converting essay level concept maps to aggregate concept map

Second, aggregate student map was created by summing up a student's concept maps for all 5 essays. Note that these aggregate maps had variable tie strengths (see figure 4.2). Refer to Jackson & Trochim (2002) for approaching concept maps using multidimensional scaling (MDS) methods.

Third, a matrix representing the degree of similarity between aggregate concept maps for any two students was created by correlating aggregate concept maps of each student with every other student. (See functional representation in table 4.3)

	1	2	3	4	5	.	.	.	60
1		1x2	1x3	1x4	.	.	.	.	1x60
2	1x2		2x3	2x4	.	.	.	.	2x60
3	1x3	2x3		3x4	.	.	.	.	3x60
4	1x4	2x4	3x4		.	.	.	.	.
5	.	.	.	.		.	.	.	.
.
.
.
60	1x60	2x60	3x60	.	.	.	.	.

'x' represents correlation between student

Table 4.4: Correlation matrix of aggregate concept maps for all 60 students with each other.

	1	2	3	4	5	.	.	.	60
1	D	1	1		1			1	
2	1	D	1		1			1	
3	1	1	D		1			1	
4				ND		1	1		1
5	1	1	1		D			1	
.				1		ND	1		1
.				1		1	ND		1
.	1	1	1		1			D	
60				1		1	1		ND

Table 4.5: Overall ED membership matrix.
(D- Design Group; ND- Non Design Group)

	1	2	3	4	5	.	.	.	60
1	D	1	1		1			1	
2	1	D	1		1			1	
3	1	1	D		1			1	
4				ND					
5	1	1	1		D			1	
.						ND			
.							ND		
.	1	1	1		1			D	
60									ND

Table 4.6: Individual ED-Design membership matrix.
(D- Design Group; ND- Non Design Group)

Fourth, overall membership networks were created by assigning unit tie strength between all students belonging to the same groups (see table 4.5 for sample education (ED) matrix).

Individual membership networks were created by assigning unit tie strength between all students belonging to one group (see table 4.6 for sample ED-Design matrix). Similarly, overall and individual matrices were created for learning style and experience.

Finally, quadratic assignment procedure (QAP) was applied between the correlation matrix created in step 3 and all membership matrices created in step 4 to get results for group level similarity in concept maps. QAP is a statistical significance testing method for comparing network data i.e. data points are not independent of each other. (For overview see Krackhardt, 1986 and Hubert, 1987)

3. How the skills are related for groups with similar concepts maps?

For groups that show similarity in concept maps, their group concept map was created by summing up aggregate concept maps of all members of the group. For example, the design group concept map is created by summing up aggregate concept maps of all design students. Within this map the hierarchy of skills based on number of members who learnt them was visually illustrated by breaking in four equal categories. The strength of ties was also illustrated by varying thickness of line to clearly depict network paths from one skill to another. (Figure 4.2)

4.5 RESULTS

The results of Kruskal-Wallis rank sum ANOVA test are shown in table 4.7. For educational background, an individual student belonging to Design or Non-Design groups significantly ($p > 0.05$) differed in the learning of 6 out of 18 skills (S1, S2, S6, L2, L3, L4). In case of a random effect (Bernoulli distribution for $p = 0.05$, $x=6$, $n=18$), there is only a 2% chance for 6 out of 18 events to be significant. Hence, this result is not a random effect -accepted.

For learning style, an individual student belonging to one of the four types significantly ($p > 0.1$) differed in the learning of 1 out of 18 skills (L6). In case of a random effect (Bernoulli distribution for $p = 0.1$, $x=1$, $n=18$), there is a 60% chance for 1 out of 18 events to be significant. Hence, this result is a random effect -rejected.

	LSI	EdB	Year
S1	0.945	0.001 ***	0.397
S2	0.232	0.021 *	0.245
S3	0.940	0.673	0.800
S4	0.220	0.769	0.209
S5	0.486	0.817	0.428
S6	0.529	0.018 *	0.701
D1	0.650	0.402	0.850
D2	0.805	0.976	0.341
D3	0.861	0.203	0.648
D4	0.733	0.706	0.197
D5	0.821	0.541	0.478
D6	0.760	0.533	0.433
L1	0.275	0.402	0.305
L2	0.850	0.028 *	0.190
L3	0.284	0.025 *	0.113
L4	0.608	0.025 *	0.370
L5	0.424	0.589	0.637
L6	0.059 .	0.203	0.663

Signif: 0 '****' 0.001 '***' 0.01 '**' 0.05 '.' 0.1 ' ' 1

Table 4.7: Kruskal-Wallis Test Results

	Estimated p-values	
	$p(f(\text{perm}) \geq f(d))$	$p(f(\text{perm}) \leq f(d))$
LSI Overall	0.559	0.441
Accommodating	0.082	0.918
Assimilating	0.408	0.592
Converging	0.479	0.521
Diverging	0.898	0.102
EdB Overall	0.022	0.978
Design	0.503	0.497
Non-Design	0.231	0.769
Year Overall	0.023	0.977
Year 1	0.032	0.968
Year 2	0.592	0.408
Year 3	0.795	0.205

Table 4.8: QAP Test Results

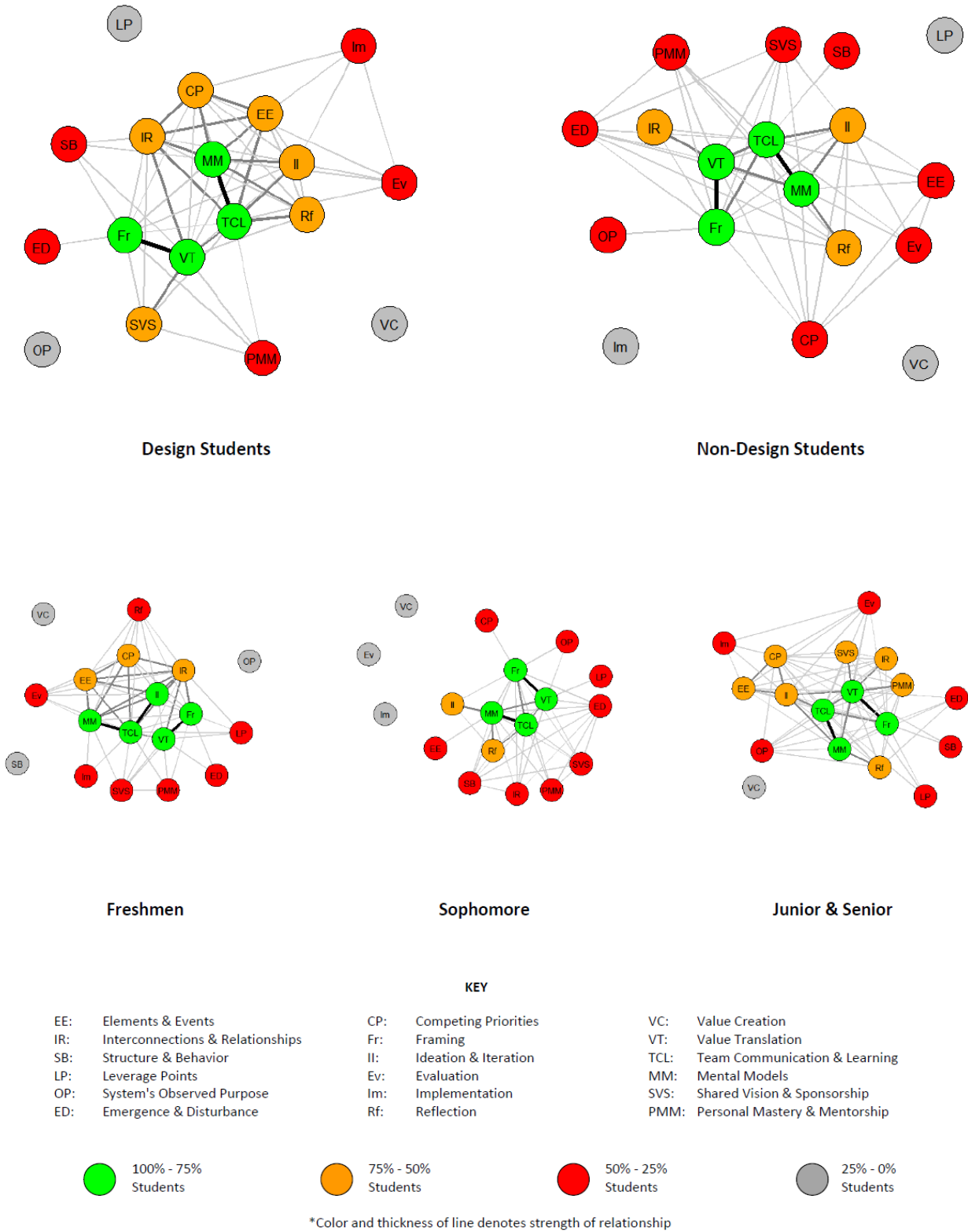


Figure 4.3: Group concept map plots for educational background (2 groups) and experience (3 groups)

The results from QAP test are shown in table 4.8. The correlation for overall education and overall experience were found to be significant and positive while overall learning style had no effect. The correlation for individual learning style – Accommodating and Diverging was found to be significant. For Accommodating, the significance was positive while for Diverging it was negative. Also, correlation for individual experience – Year 1 was found to be significant and positive. Finally, no correlation was found for individual education groups – Design or Non-Design.

Based on results of the QAP significance test, the group level concept maps for education (2 groups – Design and Non-Design) and experience (3 groups – Freshman, Sophomore and Junior & Senior) were plotted as shown in figure 4.3.

4.6 DISCUSSIONS – IMPLICATIONS FOR EDUCATORS

This study used qualitative student data from an introductory design course offered at Cornell University to explore learning behaviors of students based on their educational background, learning style and experience. Content analysis and network analysis were employed to find answers to three questions:

1. Does membership to a group associate with different skills learnt at an individual level?

Yes and the results show that educational background is the only factor that predisposes students to learn certain set of skills over others. Neither a student's intrinsic learning style nor their grade level in school makes learning particular skills easier. This means a design educator has to ensure that, especially during the early stage of teaching whole systems designing all these (S1, S2, S6, L2, L3, and L4) skills are introduced. This will make it easier for students from different academic fields to contextualize and ground their learning.

The results show that students from different educational backgrounds differed only in the learning of systems and leadership skills - no design skills were in the mix (S1, S2, S6, L2, L3, and L4). One explanation for getting such a result could be that the study was conducted in an introductory design course, thereby all students were predisposed to learning design skills i.e. the students are primed to learn design skills as it matches their expectation of a positive course outcome. This would imply that the design educators should lay equal or more emphasis on teaching systems and leadership skills. An alternative explanation could relate to student perception of the essays used as data in this study. As the essays were part of the formal evaluation of the course, the students might try to game the examination by making sure they always include design skills in their responses.

2. Does membership to a group associate with similar concept maps at a group level?

The QAP analysis showed that having the same educational background associates with similar concept maps regardless of the group the educational group they belong to. That means design students tend to have concept maps similar to each other as well as non design students have concept maps similar to each other, but a design student's map and a non-design student's map are different. This reinforces our previous finding that educational background is an important factor that determines how students learn. One possible explanation is that a student's approach to problem solving or designing is shaped by the general approach of their discipline. An interior design student might be habituated with a process of problem solving that emphasizes on select skills as it is being reinforced in all their courses which are different from those being reinforced for engineering students. Another alternative explanation could be that students discuss their problem solving approaches with peers from within their field. The

students are more likely to collaborate over their essay responses with friends from their own class and this would lead to creation of similar concept maps. The same effect was also observed for experience in school. These findings imply that a design educator should create activities that allow students from different educational backgrounds and grade levels to share and discuss their problem approach.

Students with accommodating learning style were found to have maps similar to each other. A possible explanation for this could be that accommodators' response to the written essays was very limited. This could be because the written format doesn't align with the accommodators' preference for learning by concrete experience and active experimentation.

Students with diverging learning style were the only group found to have negative correlation which means that one divergers' map was significantly different from another divergers' map. One explanation could be that divergers by definition prefer to think in different ways.

3. How the skills are related for groups with similar concepts maps?

The group concept maps shown in figure 4.3 for different educational background (design and non-design) and experience in school (freshmen, sophomore, junior and senior) can be used by educators as a network pathway to scaffold difficult concepts. All of the maps clearly show a bias towards understanding of four skills: VT, TCL, MM and Fr. This bias can be attributed to the content of the design cases that were used as sources for the essays. As we are interested in exploring the differences among groups this content bias leads to a null effect and does not interfere with the findings of our study.

It can also be observed that the Design group has a denser map in comparison to Non-Design group implying that they relate a greater variety of skills while non-design students focus

on a few core set of skills. A similar effect is seen amongst the junior and senior group implying as a student progresses through school, they start relating a variety of whole systems designing skills.

4.6.1 LIMITATIONS OF THE STUDY

Even though the findings are noteworthy, this study suffers from a number of limitations. Firstly, all the results are based on subjective coding of qualitative data, and thus prone to many errors. The coding of the whole system skills is bound to have lower construct validity. A multi-method approach will help triangulate the effects better, lending stronger support to the results. Secondly, the findings may be affected by the use of open ended essays as data. The use of other sources such as project evaluations or direct observation might yield different results for certain groups.

Thirdly, the learning style was operationalized using Kolb's LSI as it is the only instrument which categorizes participants on the basis of their problem solving inclinations. Yet, its reliability and validity as an instrument is debated in the literature (see Veres et.al, 1991; Koob & Funk, 2002; Henson & Hwang, 2002). Finding an alternate instrument that has a higher reliability without compromising on construct validity would be ideal. Finally, the findings of this study cannot be generalized beyond students. As the learning curve, peers and problem-solving context drastically changes once an individual leaves school and works in the industry a future study could be focused on using a professional participant pool. The results from high-functional interdisciplinary design teams like those at IDEO and Frog Design would prove extremely useful for the industry.

In summary, this chapter uses classroom case study to explore the preferential learning behaviors of individuals based on their problem-solving inclinations using content analysis and network analysis. It details the research methodology used and offers results and interpretations to suggest advanced teaching-learning strategies.

CHAPTER 5

SUMMARY AND RECOMMENDATIONS

This study makes three contributions to WSD theory and practice: (1) It identifies eighteen skills of Whole Systems Designing (WSD) from literature crossovers in three arenas – systems theory, design think and change leadership and organizes them into a Whole Systems Change Framework for addressing wicked problems; (2) It develops a prototype tool for teaching these skills; (3) It investigates the learning behaviors of groups of students to help design educators teach them WSD more effectively. This chapter summarizes key findings and scope for future developments in these three areas.

The study began with the motivation to understand how to ‘design’ change in this interconnected world. The following research questions were developed to explore this topic:

1. What is the skill set required for whole systems designing? Is it possible to provide a tangible model that allows an individual to comprehend and experience this collective set of skills to facilitate whole systems change?
2. What kind of educational methods and tools are required to achieve the objective of (a) teaching and (b) measuring whole systems designing skills?

5.1 A DEVELOPING FRAMEWORK FOR WHOLE SYSTEMS DESIGNING

The study began by defining WSD as any attempt of improving the human condition. In Chapter 2, this definition was further refined to: ‘*Whole system designing is implementing improvement in complex systems by the continuous process of problem solving*’. The literature on systems theory, design thinking and change leadership from the perspective of problem solving was reviewed to integrate and present 18 skills of whole systems designing in principle and

practice. (See figure 5.1 for list). Further investigation revealed indeterminacy, evolutionary design and agency of design team to be the sources of wickedness in a system. Since these characteristics prohibit the existence of one ideal solution, the best option for design teams is to create sustainable solution. Hence, the eighteen WSD skills were arranged from the perspective of sustainable change to reveal the underlying *Whole Systems Change Framework*. The author proposes organizing WSD skills in three layers: artifact layer, social layer and knowledge layer, each corresponding to skills needed for effective product design, interaction design and purpose design.



Figure 5.1: 18 Skills of Whole Systems Design

5.2 AN EVOLVING TOOL FOR TEACHING WHOLE SYSTEMS DESIGNING

To assist design educators in teaching whole systems designing, in Chapter 3, a *card-set* that highlighted the 18 skills and the three-layer conceptual framework that organizes them was developed. The goal of the design study was to create a tool that would communicate each skill in principle and practice, maintaining usability for a single student as well as a group. The card set format was chosen to facilitate learning via manipulation, physical interaction, visual suggestion and intellectual stimulation. The goals of the design process, development of the card

deck and the final prototype of the card set are presented in detail in chapter 3 (see figure 5.2 for sample card). A focus group study was conducted to evaluate the efficacy of the card set. The focus group concluded that the cards provided them with an opportunity to discuss their problem solving process *explicitly*, which enabled them to see the bigger picture and the details at the same time, and provided a platform to approach new design problems as a team. They also gave specific recommendations for using and improving the card set which included:

- Use a group card set or a big poster showing the framework for better collaboration.
- Teach using a supporting activity which highlights all 18 skills allowing the student to build the complete framework.
- Attach a ring to enhance portability and manageability of the card set.

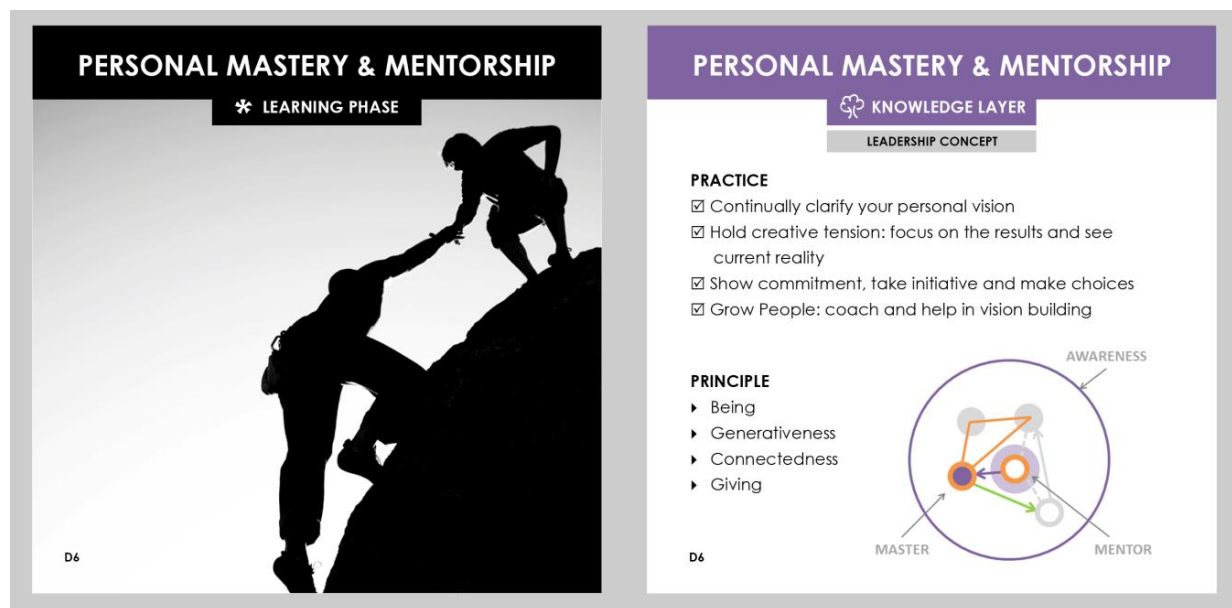


Figure 5.2: Final WSD card design layout (single card)

5.3 MAPPING STUDENT LEARNING OF WHOLE SYSTEMS DESIGN CONCEPTS

Chapter 4 explored the preferential learning behaviors of individuals based on their problem-solving inclinations by applying content analysis and network analysis to 300 essays collected from an interdisciplinary design class of 60 students over 5 months. The three key findings from this study were:

1. Using the Kruskal-Wallis ANOVA test, it was found that educational background is the only factor that predisposes students to learn certain set of skills over others. Neither a student's intrinsic learning style nor their year in school makes learning particular skills easier.
2. The QAP analysis showed that having the same educational background and experience in school associated with similar concept maps regardless of the educational group they belong to. Students with a divergent learning style were found to have concept maps significantly different from other divergent learning style students.
3. The concept maps for students of different educational backgrounds and experiences were plotted to illustrate the network pathway for these groups (refer figure 4.3, chapter 4). It was observed that design students were able to relate a greater variety of skills in comparison to non-design students.

5.4 RECOMMENDATIONS FOR FUTURE RESEARCH AND APPLICATION

This study investigated many issues about whole systems designing - the challenges for teaching it to an interdisciplinary group, and the learning outcomes of different groups. It offers many opportunities to advance research as well as create real world applications:

Recommendations for future research:

1. This study tested the cards with a small focus group, and the learning behaviors study analyzed data from students who were taught these concepts in a traditional lecture/classroom setting but not using the card set. The next logical step is to use the card set in a classroom setting and analyze their learning behavior. The results of such a study can be used in comparison to this study to conclude about the effectiveness of the WSD card set.
2. This study collected 300 data points from a small sample of 60 students belonging to the same course. Collecting data from a larger sample of students from diverse sources is recommended in order to strengthen the study.
3. The method of operationalizing individual learning style could be a factor for finding no effects for this variable. Using an instrument that has higher reliability and validity than Kolb's LSI for measuring learning style without compromising on construct validity would be ideal.
4. The findings were based on binary coding (summative content analysis) of essays. Creating a coding scale based on the depth of understanding of skills will add an important dimension approach to content analysis.
5. The findings depend on only one qualitative data source (open ended essays). The use of other sources such as project evaluations or direct observation could yield different results. A multi-method approach is recommended to help triangulate the effects better.
6. This study was conducted with students; however, there is a tremendous opportunity for understanding the learning behavior of professional teams that are involved in solving real world problems on a day to day basis. Results from professional interdisciplinary

design teams who are already expert in problem-solving but not WSD will provide great value to the industry as well as educators attempting to create new instruction strategies.

7. This study uses a very simple approach to network methods and relies on the qualitative interpretation of concept map plots. Using advanced network modeling techniques to find out the main effects and interaction effects of the groups is a logical next step for the research.

Recommendations for future applications:

1. The ‘whole systems designing card’ can be foundational in creating professional training programs or summer courses that teach complex problem solving. These programs would be filled with experiential learning activities leading to secondary outcomes like empathy, team building and collaboration. Additionally, they could serve as potential research settings for in-depth open ended evaluations.
2. The results of the learning behavior research study are of great value to educators. It is worth noting that the method for creating concept maps is not tied to the content of the course, making them scalable across different courses. Software that provides educators with teaching strategies based on inputs about a class and feedback on the effectiveness of their teaching strategies would prove extremely beneficial to all concerned.
3. The whole systems change framework introduced in this study can be developed into a complete framework for strategic change at workplaces. The author has received promising feedback from workplace professionals on the use and potential of this framework.

In closing, this study is a springboard for future research into the mechanisms and effectiveness of whole systems design education, a field of tremendous significance for developing both greater understanding and action steps in tackling the complex, wicked problems of our future.

APPENDIX A

WHOLE SYSTEMS DESIGNING: CARD SET

WHOLE SYSTEMS DESIGNING

SKILLS FOR COMPLEX PROBLEM SOLVING
IN PRINCIPLE & IN PRACTICE

WHAT IS WHOLE SYSTEMS DESIGNING?

- Whole Systems Designing Framework is a collection of 18 skills required to tackle complex problems. These have been compiled by investigating the best practices of three types of problem solvers - Systems Thinkers, Designers and Leaders.
- Each of the skills fall under Problem/Solution/Learning Phase - the three phases of problem solving.
- As there can be no one right solution to such complex problems, the skills are categorized based on their increasing importance in achieving a sustainable, long lasting impact into three layers - Artifact, Social and Knowledge.
- This card set can be used individually or collectively for (a) Case Analysis to understand these skills in practice, (b) Problem Solving for holistic and sustainable solutions.

ABOUT

- The Whole Systems Designing card set was developed as a part of the masters work by Pranav Gupta under the guidance of Sheila Danko at Cornell University, 2013.
- Photo Credits: Luna Zang (15), Rishikesh Karande (1), Anonymous Internet Source (2)

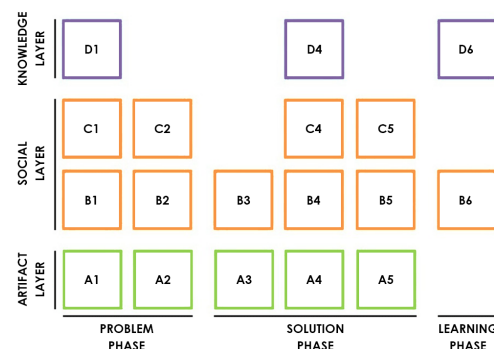
WHOLE SYSTEMS DESIGN SKILLS

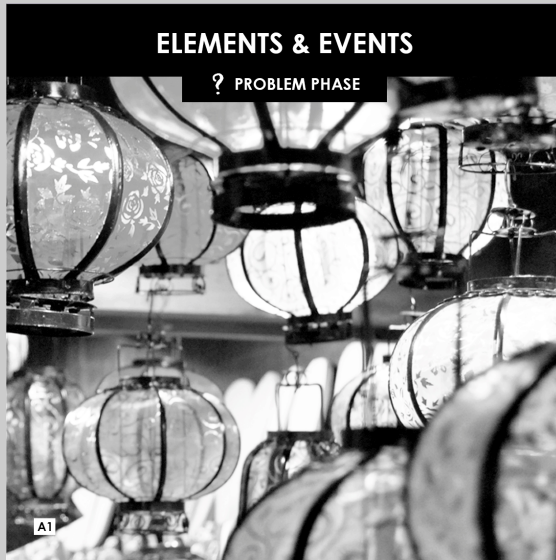
AREA OF EXPERTISE

A1	Elements & Events	Systems Thinking
A2	Value Creation	Leadership Concept
A3	Ideation & Iteration	Design Process
A4	Evaluation	Design Process
A5	Implementation	Design Process
B1	Interconnections & Relationships	Systems Thinking
B2	Competing Priorities	Design Process
B3	Framing	Design Process
B4	Value Translation	Leadership Concept
B5	Team Learning & Communication	Leadership Concept
B6	Reflection	Design Process
C1	Structure & Behavior	Systems Thinking
C2	Leverage Points	Systems Thinking
C4	Mental Models	Leadership Concept
C5	Shared Vision & Sponsorship	Leadership Concept
D1	System's Observed Purpose	Systems Thinking
D4	Emergence & Disturbance	Systems Thinking
D6	Personal Mastery & Mentorship	Leadership Concept

WHOLE SYSTEMS DESIGNING

FRAMEWORK





ELEMENTS & EVENTS

ARTIFACT LAYER

SYSTEMS THINKING

PRACTICE

- ☑ Observe events that reveal problems
- ☑ Identify surface symptoms
- ☑ Identify all the components and players by talking to / taking perspective of multiple stakeholders
- ☑ Iteratively expand and bound the problem space

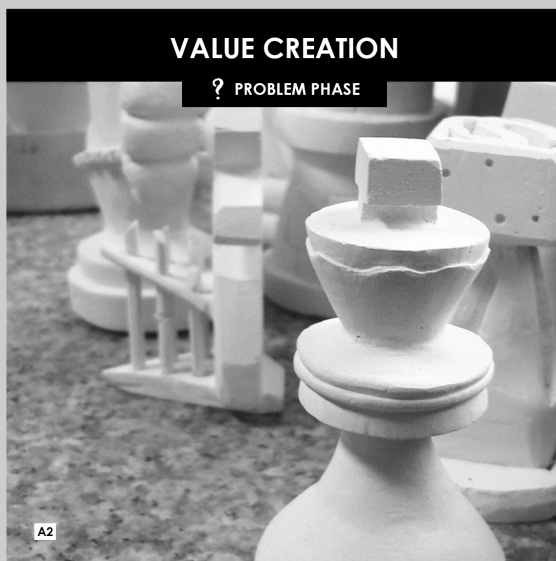
PRINCIPLE

- Distinction
- Problem Recognition
- Elements influence Events

SUBJECTS:
PEOPLE/
GROUPS

OBJECTS:
PRODUCTS

A1



VALUE CREATION

ARTIFACT LAYER

LEADERSHIP CONCEPT

PRACTICE

- ☑ Identify the Latent potential
- ☑ Connect this to unfulfilled needs
- ☑ Understand why and how the value is being added
- ☑ Define the problem by attempting multiple solutions

PRINCIPLE

- Desired Purpose
- Vision
- Opportunity Recognition

ADD VALUE

ENHANCE
FUNCTIONALITY

A2

IDEATION & ITERATION

! SOLUTION PHASE



IDEATION & ITERATION

ARTIFACT LAYER

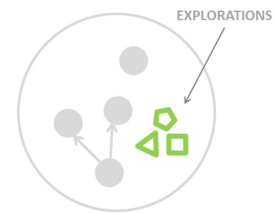
DESIGN PROCESS

PRACTICE

- ☑ Create a line of exploration that reformulates the existing pattern and suggests a direction towards solution
- ☑ Use prototypes to explore ideas, elaborate requirements, refine specifications and test functionality
- ☑ Generate, refine and select concepts

PRINCIPLE

- Creativity
- Perseverance
- Possibilities of Action



A3

EVALUATION

! SOLUTION PHASE



EVALUATION

ARTIFACT LAYER

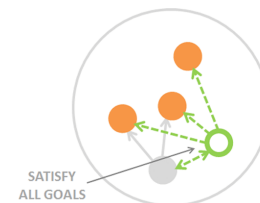
DESIGN PROCESS

PRACTICE

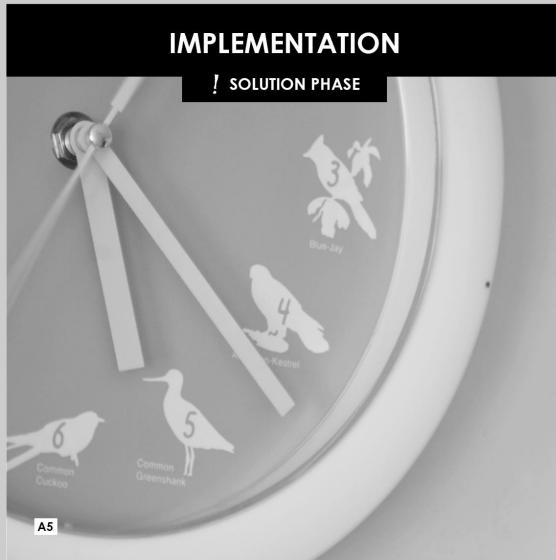
- ☑ Balance potential benefits and liabilities of situation
- ☑ Check against goals of function, form, economy and time
- ☑ Approach ideas and action plans with fresh eyes
- ☑ Seek feedback from stakeholders and acknowledge prejudice

PRINCIPLE

- Decision Criteria
- Feedback



A4



IMPLEMENTATION

ARTIFACT LAYER

DESIGN PROCESS

PRACTICE

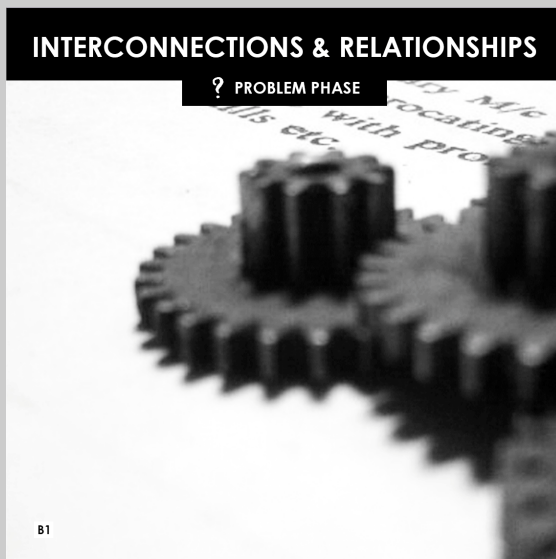
- ☑ Give form to the idea
- ☑ Have a plan and put the plans into effect
- ☑ Balance and align the parts with the whole
- ☑ Examine progress and have contingency plans
- ☑ Do it together and create short term wins

PRINCIPLE

- Action Steps
- Process of Growth
- Translation into Reality

TRANSLATE INTO REALITY

A5



INTERCONNECTIONS & RELATIONSHIPS

SOCIAL LAYER

SYSTEMS THINKING

PRACTICE

- ☑ Observe and examine elements in relation to the whole
- ☑ Identify delays, balancing and reinforcing feedback loops
- ☑ Analyze various flows between physical elements
- ☑ Empathize to understand human needs and relations

PRINCIPLE

- Causality
- Information Flow
- Connections influence Relations

INFORMATION FLOWS

LOOPS

B1

COMPETING PRIORITIES

? PROBLEM PHASE



B2

COMPETING PRIORITIES

👤 SOCIAL LAYER

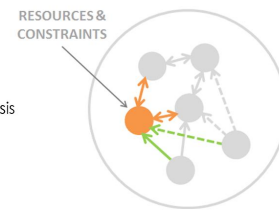
DESIGN PROCESS

PRACTICE

- ☑ Identify crucial resources and constraints
- ☑ Distill the subjective and objective responses to look for and make priorities
- ☑ Set clear objectives with a high level, simplistic and holistic systems view of the problem encapsulated in the goal

PRINCIPLE

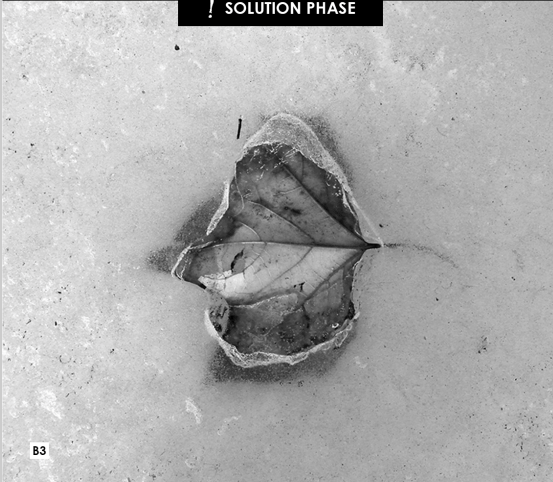
- ▶ Core Paradox
- ▶ Interface between Analysis and Synthesis



B2

FRAMING

! SOLUTION PHASE



B3

FRAMING

👤 SOCIAL LAYER

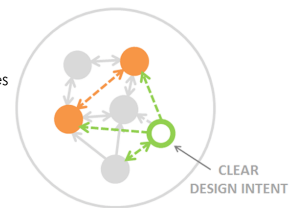
DESIGN PROCESS

PRACTICE

- ☑ Recognize and Break the influence of initial design
- ☑ Surface your team's tacit organizing principles at the outset: Priorities and Contexts
- ☑ Formulate the problem: Set its boundaries, select specific elements & relations for attention and impose a coherence guiding subsequent moves

PRINCIPLE

- ▶ Assumptions
- ▶ Conceptual Guidelines
- ▶ Design Objectives



B3

VALUE TRANSLATION

! SOLUTION PHASE



VALUE TRANSLATION

! SOCIAL LAYER

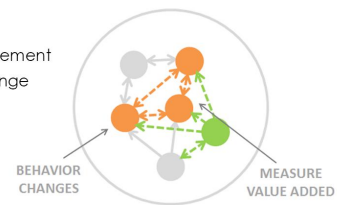
LEADERSHIP CONCEPT

PRACTICE

- ☑ Measure qualitative & quantitative value generated
- ☑ Identify & measure effects of unforeseen benefits and problems
- ☑ Identify stakeholder behaviors altered or reinforced
- ☑ Understand attitudes towards anticipated change
- ☑ Review actions to determine how to proceed

PRINCIPLE

- Impact Measurement
- Process of Change



B4

TEAM LEARNING & COMMUNICATION

! SOLUTION PHASE



TEAM LEARNING & COMMUNICATION

! SOCIAL LAYER

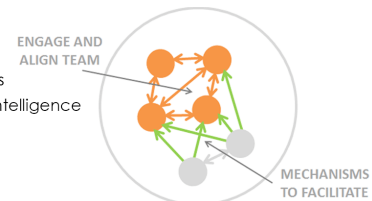
LEADERSHIP CONCEPT

PRACTICE

- ☑ Suspend assumptions and surface your defensiveness
- ☑ Develop capacity to voice disagreements
- ☑ Encourage dialogues to function as a whole
- ☑ Acknowledge risks and issues to foster proactive, honest and sensitive discussions
- ☑ Provide non-threatening Feedback Mechanisms

PRINCIPLE

- Alignment
- Inclusiveness
- Collective Intelligence



B5



REFLECTION

SOCIAL LAYER

DESIGN PROCESS

PRACTICE

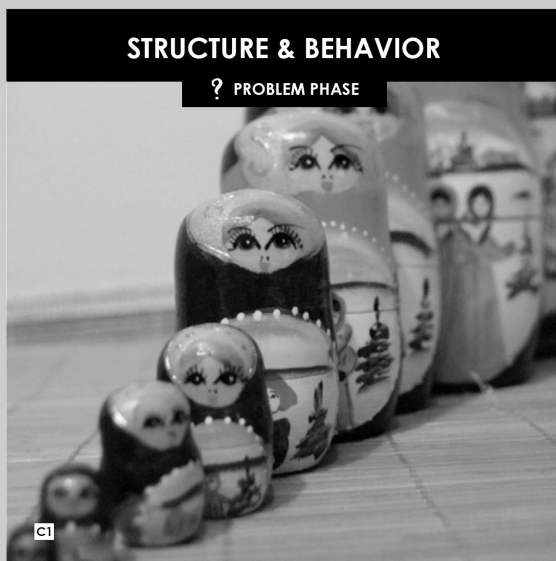
- ☑ Reflect objectively and seek feedback from peers
- ☑ Take a critical view at the process and compare actions with consequences
- ☑ Identify behaviors altered or reinforced, skills developed and knowledge acquired
- ☑ Link insights to further problem solving journeys

PRINCIPLE

- Feedback
- Process Insights
- Commencement

INSIGHTS AND PROCESS LEARNING

B6



STRUCTURE & BEHAVIOR

SOCIAL LAYER

SYSTEMS THINKING

PRACTICE

- ☑ Realize the system is more than the sum of its parts
- ☑ Map all the elements and interconnections and identify archetypes
- ☑ Observe and analyze behavior over time
- ☑ Change structure, not just elements to alter function

PRINCIPLE

- Hierarchy
- Self-Organizing Pattern
- Structures influence Behavior

AGGREGATE BEHAVIOR

C1

LEVERAGE POINTS

? PROBLEM PHASE



LEVERAGE POINTS

👤 SOCIAL LAYER

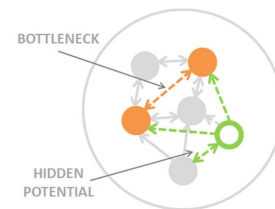
SYSTEMS THINKING

PRACTICE

- ☑ Search for insights within the problem that correspond to disproportionate shifts
- ☑ Identify parts of the structure which maximize desired change and minimize resource requirements
- ☑ Identify elements and relations which are central or perform the bottle-neck functions

PRINCIPLE

- ▶ Non-Linearity
- ▶ Non-Redundancy



C2

MENTAL MODELS

! SOLUTION PHASE



MENTAL MODELS

👤 SOCIAL LAYER

LEADERSHIP CONCEPT

PRACTICE

- ☑ Question & Test Assumptions individually and collectively
- ☑ Distinguish Data from Abstract Conclusions based on Data
- ☑ Balance inquiry with advocacy
- ☑ Reveal gaps between current and desired culture

PRINCIPLE

- ▶ Openness
- ▶ Love of Truth
- ▶ Freedom from Bias



C4

SHARED VISION & SPONSORSHIP

! SOLUTION PHASE



SHARED VISION & SPONSORSHIP

👤 SOCIAL LAYER

LEADERSHIP CONCEPT

PRACTICE

- ☑ Build a common vision: share personal visions, listen to others and give freedom of choice
- ☑ Investigate and acknowledge current reality collectively
- ☑ Show continued confidence and belief in others ability to change and grow

PRINCIPLE

- ▶ Commonality of Purpose
- ▶ Partnership
- ▶ Mutual Trust



C5

SYSTEM'S OBSERVED PURPOSE

? PROBLEM PHASE



SYSTEM'S OBSERVED PURPOSE

🧠 KNOWLEDGE LAYER

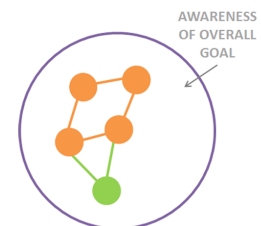
SYSTEMS THINKING

PRACTICE

- ☑ Identify the 'goal' seeking tendency by analyzing the behavior
- ☑ Identify the source of functional resilience
- ☑ Discover where and how is the diversity and redundancy included

PRINCIPLE

- ▶ Holism
- ▶ Interconnectedness



D1

EMERGENCE & DISTURBANCE

! SOLUTION PHASE



D4

EMERGENCE & DISTURBANCE



KNOWLEDGE LAYER

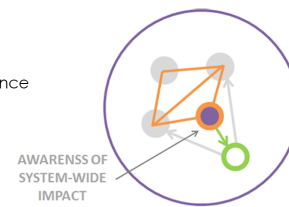
SYSTEMS THINKING

PRACTICE

- ☑ Get the beat of the system and go for good of the whole
- ☑ Realize that the resultant system is always the reaction of the existing to the designed
- ☑ Honor, respect and distribute information, all designs only change the world in small steps

PRINCIPLE

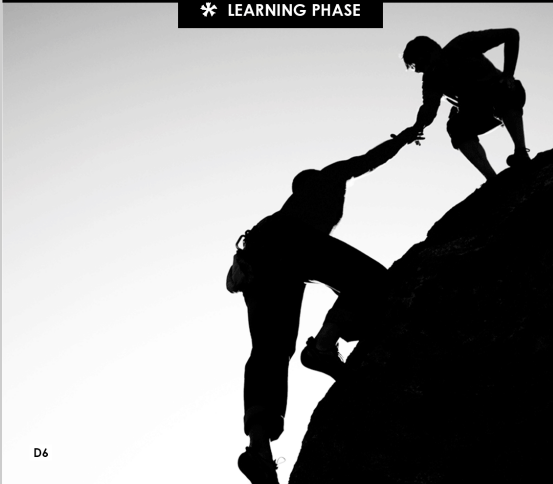
- ▶ Continuum
- ▶ Functional Resilience



D4

PERSONAL MASTERY & MENTORSHIP

* LEARNING PHASE



D6

PERSONAL MASTERY & MENTORSHIP



KNOWLEDGE LAYER

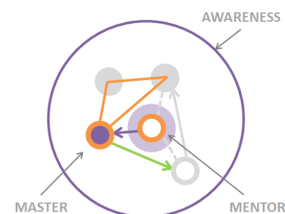
LEADERSHIP CONCEPT

PRACTICE

- ☑ Continually clarify your personal vision
- ☑ Hold creative tension: focus on the results and see current reality
- ☑ Show commitment, take initiative and make choices
- ☑ Grow People: coach and help in vision building

PRINCIPLE

- ▶ Being
- ▶ Generativeness
- ▶ Connectedness
- ▶ Giving



D6

APPENDIX B

LITERATURE REVIEW SCORING RUBRIC (BOOTE AND BEILE, 2005)

Literature Review Scoring Rubric

Category	Criterion	1	2	3	4
1. Coverage	A. Justified criteria for inclusion and exclusion from review.	Did not discuss the criteria inclusion or exclusion	Discussed the literature included and excluded	Justified inclusion and exclusion of literature	
2. Synthesis	B. Distinguished what has been done in the field from what needs to be done.	Did not distinguish what has and has not been done	Discussed what has and has not been done	Critically examined the state of the field	
	C. Placed the topic or problem in the broader scholarly literature	Topic not placed in broader scholarly literature	Some discussion of broader scholarly literature	Topic clearly situated in broader scholarly literature	
	D. Placed the research in the historical context of the field.	History of topic not discussed	Some mention of history of topic	Critically examined history of topic	
	E. Acquired and enhanced the subject vocabulary.	Key vocabulary not discussed	Key vocabulary defined	Discussed and resolved ambiguities in definitions	
	F. Articulated important variables and phenomena relevant to the topic.	Key variables and phenomena not discussed	Reviewed relationships among key variables and phenomena	Noted ambiguities in literature and proposed new relationships	
	G. Synthesized and gained a new perspective on the literature.	Accepted literature at face value	Some critique of literature	Offered new perspective	
3. Methodology	H. Identified the main methodologies and research techniques that have been used in the field, and their advantages and disadvantages.	Research methods not discussed	Some discussion of research methods used to produce claims	Critiqued research methods	Introduced new methods to address problems with predominant methods
	I. Related ideas and theories in the field to research methodologies.	Research methods not discussed	Some discussion of appropriateness of research methods to warrant claims	Critiqued appropriateness of research methods to warrant claims	
4. Significance	J. Rationalized the practical significance of the research problem.	Practical significance of research not discussed	Practical significance discussed	Critiqued practical significance of research	
	K. Rationalized the scholarly significance of the research problem.	Scholarly significance of research not discussed	Scholarly significance discussed	Critiqued scholarly significance of research	
5. Rhetoric	L. Was written with a coherent, clear structure that supported the review.	Poorly conceptualized, haphazard	Some coherent structure	Well developed, coherent	

Note: The column-head numbers represent scores for rating dissertation literature reviews on 3-point and 4-point scales (endnote 4 explains our choice of the two types of scales). Adapted from *Doing a Literature Review: Releasing the Social Science Research Imagination* (p. 27), by Christopher Hart, 1999, London, SAGE Publications. Copyright 1999 by SAGE Publications. Adapted with permission.

REFERENCES

- Ackoff, R. (1981). *Creating the corporate future*. New York: John Wiley.
- Anderson, V., & Johnson, L. (1997). *Systems thinking basics: From concepts to causal loops*. Cambridge, Mass: Pegasus Communications.
- Appadurai, A. (2001). Grassroots globalization and the research imagination. In A. Appadurai, ed. *Globalization*, 1-21. Durham, NC: Duke University Press.
- Argyris, C., & Schön, D. (1978). *Organizational Learning: A theory of action perspective*. Reading MA: Addison-Wesley.
- Arup Foresight. (2009). *Drivers of change*. New York: Prestel. Retrieved from <http://www.driversofchange.com/make/research/doc/>
- Asimov, I., & Shulman, J. (1988). *Isaac Asimov's book of science and nature quotations*. New York: Weidenfeld & Nicolson. (pp. 18)
- Avolio, B. J., Walumbwa, F. O., & Weber, T. J. (January 01, 2009). Leadership: current theories, research, and future directions. *Annual Review of Psychology*, 60, 421-49.
- Banathy, B.H. (1996). *Designing social systems in a changing world*. New York: Plenum Press
- Barrett, R. (2003). *Libérer l'âme de l'entreprise: Bâtir une organisation visionnaire guidée par les valeurs*. Bruxelles: De Boeck.
- Barrett, R. (2006). *Building a values-driven organization: A whole system approach to cultural transformation*. Burlington, MA: Butterworth-Heinemann.
- Beinecke, R. H. (2009). Introduction: Leadership for wicked problems. *The Innovation Journal: The Public Sector Innovation Journal*, 14(1),
- Bertalanffy, L. (1969). *General system theory: Foundations, development, applications*. New York: G. Braziller.
- Boland, R. J., & Collopy, F. (Eds.) (2004) 'Design matters for management', in *Managing as Designing*, Stanford University Press, Stanford, CA, 3-18.
- Boote, D. N., & Beile, P. (August 01, 2005). Scholars Before Researchers: On the Centrality of the Dissertation Literature Review in Research Preparation. *Educational Researcher*, 34, 6, 3-15.
- Boyatzis, R. E. (2006). Intentional change theory from a complexity perspective. *Journal of Management Development*, 25, 607–623.
- Brown, T. (2008) Design Thinking. *Harvard Business Review*, 84-92.
- Brown, T. (2009) *Change by Design*. New York, NY: HarperCollins.

- Buchanan, R. (1992) Wicked problems in design thinking. *Design Issues*, 8, 2, 5-21.
- Cabrera, D. (2006). *Systems Thinking*. NY, Cornell University. Ph.D.
- Cabrera, D., & Colosi, L. (2009). *Thinking at every desk: How four simple thinking skills will transform your teaching, classroom, school, and district*. Ithaca, N.Y: Research Institute for Thinking in Education.
- Capra, F. (1990). *The Turning Point: Science, Society, and the Rising Culture*. 8th impression. ed. London: Fontana.
- Capra, F. (1997). *The Web of Life: a New Scientific Understanding of Living Systems*. 1st Anchor Books trade paperback ed. New York, N.Y.: Anchor Books.
- Capra, F. (2000). *The Tao of Physics: An Exploration of the Parallels Between Modern Physics and Eastern Mysticism*. 4th ed. Boston: Shambhala.
- Capra, F. (2002). *The Hidden Connections: Integrating the Hidden Connections Among the Biological, Cognitive, and Social Dimensions of Life*. 1st ed. New York: Doubleday.
- Capra, F. (2009). *Life and Leadership: A systems approach management seminars by fritjof capra*. Retrieved from <http://www.fritjofcapra.net/summary.html>
- Checkland, P. (1999). *Soft systems methodology: A 30-year retrospective*. Chichester: John Wiley.
- Chimero, F. (2012). *The shape of design*. (1st ed.). Minnesota: Shapco Printing. Retrieved from <http://www.shapeofdesignbook.com>
- Chomsky, N. (2013, June 17). *A roadmap to a just world -- people reanimating democracy*. Retrieved from <http://www.chomsky.info/talks/20130617.htm>
- Churchman, C. W. (December 01, 1967). Guest Editorial: Wicked Problems. *Management Science*, 14, 4.)
- Coleman L. (2009, February). Liz Coleman: A call to reinvent liberal arts education [Video file]. Retrieved from http://www.ted.com/talks/liz_coleman_s_call_to_reinvent_liberal_arts_education.html
- Conklin, J. (2005). Wicked Problems & Social Complexity. *Dialogue Mapping: Building Shared Understanding of Wicked Problems*. Wiley
- Corder, Gregory W.; Foreman, Dale I. (2009). *Nonparametric Statistics for Non-Statisticians*. Hoboken: John Wiley & Sons. pp. 99–105.
- Covey, S. R. (January 01, 2005). Four Traits of Great Leaders: Find your special role and purpose. *Leadership Excellence*, 22, 11, 4.
- Cross, N. (1989). *Engineering design methods*. Chichester England: Wiley.

- Cross, N. (2001) Designerly Ways of Knowing: Design Discipline Versus Design Science. *Design Issues*, 17, 3, 49-55.
- Cross, N. (2007). *Designerly Ways of Knowing*, Birkhauser, Basel, Switzerland.
- Cross, N. (2010) Design Thinking as a Form of Intelligence. In: K. Dorst, S. Stewart, I. Staudinger, B. Paton & A. Dong (Eds.), *Proceedings of the 8th Design Thinking Research Symposium (DTRS8)*, 99-105
- Cross, N. (2011). *Design thinking: Understanding how designers think and work*. Oxford: Berg.
- Cross, N. (October 01, 1982). Designerly ways of knowing. *Design Studies*, 3, 4, 221-227.
- Cross, N., Christiaans h. & Dorst K. (eds) (1996). *Analysing Design Activity*, wiley, chichester.
- Cross, N., Dorst K. & Roozenburg N. (eds) (1992). *Research in Design Thinking*, Delft University Press, Delft, 1992.
- Danko, S. (September 01, 2003). Nurturing Whole Person Development and Leadership Through Narrative. *Journal of Interior Design*, 29, 82-96.
- Dorst, K. (1997). *Describing Design-A Comparison of Paradigms*. Thesis TUDelft, The Netherlands
- Dorst, K. (2006). 'Design Problems and Design Paradoxes', *Design Issues*, 22, 3, 4-17.
- Dorst, K. (2009). 'Layers of Design: Understanding Design Practice', in: Proceedings of IASDR 2009 (International Association of Societies of Design Research), *Design Rigour & Relevance*, IASDr & Korea Society of Design Science, Seoul.
- Dorst, K. (2010) The Nature of Design Thinking. In: K. Dorst, S. Stewart, I. Staudinger, B. Paton & A. Dong (Eds.), *Proceedings of the 8th Design Thinking Research Symposium (DTRS8)*, 131-139
- Dorst, K. (January 01, 2011). The core of design thinking and its application. *Design Studies*, 32, 6, 521-532.
- Dziersk, M. (March 2006). *Design Thinking... What is That?* Article at fastcompany.com
- Faste, R. (1994). "Ambidextrous Thinking", *Innovations in Mechanical Engineering Curricula for the 1990s*, American Society of Mechanical Engineers.
- Forrester, J. W. (1990). *Principles of systems*. Cambridge, Mass: Productivity Press.
- Francois, C. (2004). *International Encyclopedia of Systems And Cybernetics*. 2nd edition ed. Munchen: K G Saur North Amer Research.
- Gann, D. and Salter, A. (2001). Interdisciplinary education for design professionals. In Spence, R., S. Macmillan, and P. Kirby, ed. *Interdisciplinary design in practice*. Reston, VA: Thomas Telford.
- Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. New York: Basic Books.

- Garud, R., Jain, S., & Tuertscher, P. (January 01, 2008). Incomplete by Design and Designing for Incompleteness. *Organization Studies*, 29, 3, 351-371.
- Gell-Mann M. (1995). What Is Complexity. *Complexity*, 1,1.
- Gladwell, M. (2000). *The tipping point : how little things can make a big difference*. 1st ed. Boston: Little, Brown.
- Guindon, R. (1990). Designing the Design Process: Exploiting Opportunistic Thoughts. *Human-Computer Interaction*, 5, 305-344.
- Hart, C. (1998). *Doing a literature review: Releasing the social science research imagination*. London: Sage Publications.
- Hawken, P. (2010). *The ecology of commerce: A declaration of sustainability*. New York: Harper Business.
- Henson, R. K., & Hwang, D.-Y. (August 01, 2002). Variability and Prediction of Measurement Error in Kolb's Learning Style Inventory Scores: A Reliability Generalization Study. *Educational and Psychological Measurement*, 62, 4, 712-27.
- Hubert, L. J. (1987). *Assignment methods in combinatorial data analysis*. New York: M. Dekker.
- Ivanov, K., Ackoff, R. L., & Emery, F. E. (January 01, 1973). Review of On Purposeful Systems. *Acta Sociologica*, 16, 4, 357-359.
- Jackson, K. M., & Trochim, W. M. K. (January 01, 2002). Concept Mapping as an Alternative Approach for the Analysis of Open-Ended Survey Responses. *Organizational Research Methods*, 5, 4, 307-336
- Jackson, P. L. (2010). *Getting design right: A systems approach*. Boca Raton, FL: CRC Press.
- Koberg, D., & Bagnall, J. (1974). *The universal traveler: a soft-systems guide: To creativity, problem-solving, and the process of design*. Los Altos, Calif: W. Kaufmann.
- Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, N.J: Prentice-Hall.
- Kolb, D. A., Boyatzis, R. E., & Mainemelis, C. (2000). Experiential learning theory: Previous research and new directions. In R. J. Sternberg & L. Zhang (Eds.), *Perspectives on thinking, learning, and cognitive styles* NJ: Lawrence Erlbaum.
- Kolb, D.A. (1976). *Learning style inventory*. Boston: McBer and Company.
- Koob, J. J., & Funk, J. (January 01, 2002). Kolb's Learning Style Inventory: Issues of Reliability and Validity. *Research on Social Work Practice*, 12, 2, 293-308.

- Kotter, J. (2011, 7 12). Change management vs. change leadership -- what's the difference?. *Forbes*. Retrieved from <http://www.forbes.com/sites/johnkotter/2011/07/12/change-management-vs-change-leadership-whats-the-difference/>
- Kotter, J. P. (1996). *Leading change*. Boston, Mass: Harvard Business School Press.
- Krackhardt, D. M. (1986). *QAP partialling as a test of spuriousness*. Ithaca, N.Y.: Johnson Graduate School of Management.
- Krippendorff, K. (1980). *Content analysis: An introduction to its methodology* (Vol. 5). Newbury Park, CA: Sage.
- Laozi, Feng G-f, English J. *Tao Te Ching*. 1st ed. New York: Knopf; 1972.
- Levins, Richard. (1998). *Looking at the Whole: Toward a Social Ecology of Health*. Robert Ebert Lecture, Kansas Health Foundation.
- Lidwell, W., Holden, K., Butler, J., & Elam, K. (2010). *Universal principles of design: 125 ways to enhance usability, influence perception, increase appeal, make better design decisions, and teach through design*. Beverly, Mass: Rockport Publishers.
- Lombard, M., Snyder-Duch, J., & Bracken, C. C. (2004). Practical resources for assessing and reporting intercoder reliability in content analysis research projects. Retrieved April, 19, 2004.
- Marieb, E. & Hoehn, K. (2007). *Human anatomy and physiology*. (7th ed.). San Francisco: Pearson Benjamin Cummings.
- Marsh, G. P. (1864). *Man and nature*. Reprint, Cambridge: Harvard Univ. Press. 1967. (pp. 29-37)
- Meadows, D. H., & Wright, D. (2008). *Thinking in systems: A primer*. White River Junction, Vt: Chelsea Green Pub.
- Meinel, C., & Leifer, L. (2011). *Design thinking: Understand - improve - apply*. Berlin: Springer.
- Michalko, M. (1994). *ThinkPak*. Berkeley: Ten Speed Press. Retrieved from <http://www.amazon.com/Thinkpak-Michael-Michalko/dp/0898156076>
- Midgley G, ed. (2003). *Systems Thinking, Volume I: General Systems Theory, Cybernetics and Complexity*. London: Sage Publications. No. 1.
- Midgley G, ed. (2003). *Systems Thinking, Volume II: Systems Theories and Modelling*. London: Sage Publications. No. 2.
- Midgley G, ed. (2003). *Systems Thinking, Volume III: Second Order Cybernetics, Systemic Therapy and Soft Systems Thinking*. London: Sage Publications.
- Midgley G, ed. (2003). *Systems Thinking, Volume IV: Critical Systems Thinking and Systemic Perspectives on Ethics, Power and Pluralism*. London: Sage Publications.

- Nonaka, I., & Takeuchi, H. (1995). *The Knowledge Creating Company*. New York: Oxford University Press.
- Nonaka, I., Toyama, R., & Konno, N. (January 01, 2000). SECI, Ba and Leadership: a Unified Model of Dynamic Knowledge Creation. *Long Range Planning*, 33, 1, 5-34.
- Oech, R. (1989). *Creative whack pack*. Stamford: United States Games Systems. Retrieved from <http://creativewhack.com/product.php?productid=64>
- Orr, D. W. (2002). *The nature of design: Ecology, culture, and human intention*. Oxford: Oxford University Press. (pp. 96)
- Peña, W., & Parshall, S. (2001). *Problem seeking: An architectural programming primer*. New York: Wiley.
- Pourdehnad J., Wexler E. and Wilson D. (2011). Integrating Systems Thinking & Design Thinking. *The Systems Thinker*. 22(9): 2-6.
- Raffaelli, D. G., & Frid, C. (2010). *Ecosystem ecology: A new synthesis*. Cambridge: Cambridge University Press.
- Rittel, H. W. J. (1972). On the Planning Crisis: Systems Analysis of the 'First and Second Generations'. *Bedrifts Økonomen*. 8: 390–396.
- Rittel, H. W. J., & Webber, M. M. (1972). *Dilemmas in a general theory of planning*. Berkeley: Institute of Urban & Regional Development, University of California.
- Roberts, N.C. (2000). Wicked Problems and Network Approaches to Resolution.. *The International Public Management Review*. 1, 1
- Roozenburg, N.F.M. & Eekels J. (1995). *Product Design: Fundamentals and Methods*. Chichester: Wiley.
- Schwarz E. (1996) Streams of Systemic Thought. May 2001 ed. Neuchâtel, Switzerland.
- Senge, P. M. (1990). *The fifth discipline: The art and practice of the learning organization*. New York: Doubleday/Currency.
- Senge, P. M. (1994). *The Fifth discipline fieldbook: Strategies and tools for building a learning organization*. New York: Currency, Doubleday.
- Sevaldson, B. (2009). Why should we and how can we make the design process more complex? a new look at the systems approach in design. In M. Berg (Ed.), *Shaping Futures* Oslo: Oslo School of Architecture and Design.
- Sevaldson, B. (2011). Giga-Mapping: Visualisation For Complexity And Systems Thinking In Design. *Nordic Design Research Conference*, Helsinki www.nordes.org.
- Simon, H. A. (1981). *The sciences of the artificial*. Cambridge, Mass: MIT Press.

- Stone, M. K., & Barlow, Z. (2005). *Ecological literacy: Educating our children for a sustainable world*. San Francisco: Sierra Club Books.
- Strogatz SH. (2003). *Sync : the emerging science of spontaneous order*. 1st ed. New York: Hyperion.
- Sweeney, L. B. & Sterman, J. D. (2000). Bathtub dynamics: initial results of a systems thinking inventory. *System Dynamics Review*, 16, 4, 249–286.
- Teal, R. (October 01, 2010). Developing a (Non-Linear) Practice of Design Thinking. *International Journal of Art & Design Education*, 29, 3, 294-302.
- Telier, A. (Project). (2011). *Design things*. Cambridge, Mass: MIT Press.
- Tinsley, H. E. A. & Weiss, D. J. (2000). Interrater reliability and agreement. In H. E. A. Tinsley & S. D. Brown, Eds., *Handbook of Applied Multivariate Statistics and Mathematical Modeling*, pp. 95-124. San Diego, CA: Academic Press.
- Trochim WM, Cabrera DA, Milstein B, Gallagher RS, Leischow SJ. (2006). Practical Challenges of Systems Thinking and Modeling in Public Health *American Journal of Public Health*. 96(3):1-9.
- Veres, J. G., Sims, R. R., & Locklear, T. S. (March 01, 1991). Improving the Reliability of Kolb's Revised Learning Style Inventory. *Educational and Psychological Measurement*, 51, 1, 143-150.
- Vygotskiĭ, L. S., & Cole, M. (1978). *Mind in society: The development of higher psychological processes*. Cambridge: Harvard University Press.
- Wheatley MJ. (1999). *Leadership and the new science: discovering order in a chaotic world*. 2nd ed. San Francisco: Berrett-Koehler Publishers.
- Wheatley, M. (2011). *The big learning event*. Retrieved from <http://www.margaretwheatley.com/articles/Wheatley-The-Big-Learning-Event.pdf>